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FRONTISPIECE

Gilbert Dennison Harris

(1864-1952)

BULLETINS
OF
AMERICAN PALEONTOLOGY

* * *

Vol 35

* * *

No. 146

MEMORIAL
(1864-1952)
Gilbert Dennison Harris

By

Katherine Van Winkle Palmer
Paleontological Research Institution

November 23, 1953

Paleontological Research Institution
Ithaca, New York
U.S.A.

From the lessons of our own experiences, as well as from the lives of others, we are led irresistibly to the conclusion that the most natural way of acquiring a knowledge of the earth is to be associated in Nature's laboratory—the field—with some experienced person who is carrying on original investigations.

—G. D. HARRIS, 1900.

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MEMORIAL

GILBERT DENNISON HARRIS
(1864-1952)

By

KATHERINE V. W. PALMER

Gilbert Dennison Harris, founder of the Bulletins of American Paleontology, Palaeontographica Americana, and the Paleontological Research Institution, died at his home, 126 Kelvin Place, in Ithaca, New York, on December 4, 1952.

Professor Harris was born on a farm near Jamestown, New York, October 2, 1864,[1] the fourth of six children of Francis E. and Lydia Helen (Crandall) Harris. Both parents, descendants of early New England settlers of English and Welsh ancestry, "went West" as young people to join pioneering relatives in northern Chautauqua County along the shore of Lake Erie. Their own home was later established in the southern part of the county. The first child, Cora E. Harris, died at 88, and their mother was 86 at her death. The older son, Rollin Arthur Harris (1863-1918) was a brilliant mathematical student. He was the author of the monumental "Manual of Tides" and the mathematical designer of the then new and "most satisfactory tide predicting machine" and was associated with the United States Coast and Geodetic Survey at the time of his death. Florence B. Harris, the youngest and now the only surviving member of the family, lives in Falconer, New York, in the vicinity of the old homestead.

The name of an aunt, Melinda Burton (Mrs. H. B.) who lived to be 106, is perpetuated in paleontological history by the "Burton Sponge." It was found on her farm near Ripley, Chautauqua County, New York. A restoration of it now stands in the New York State Museum. This gigantic fossil glass sponge,[2] a *Ceratodictya,* is estimated to be over 10 feet in length, the largest Devonian (Chemung beds) glass sponge yet discovered.

Gilbert Harris's first schooling was in the one-room building known as "Peck Settlement school house" which stood on land adjoining his father's farm. Both Gilbert and his brother Rollin attended what was then known as the Jamestown Union School and Collegiate Institute, walking four miles each way to do so. The distance may have helped to encourage them to complete this phase of their education in the fewest possible terms. Each boy was to win a scholarship and eventually go to Cornell University after an interlude of country-school teaching. This experience was a grim one for the younger brother trying to cope with Dry Brook District School problems by day and unable to find comfort at night in an attic room heated only by a kerosene lamp.

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[1] The author gratefully acknowledges the help of Rebecca S. Harris for the notes on the family history.

[2] Clarke, J. M., New York State Mus. Bull., Nos. 239, 240, 1922, p. 24, 17th Rept. Dir., 1920-21; Geol. Soc. America, v. 34, No. 1, p. 127, 1923; 18th Rept. Dir. New York State Mus., New York State Mus. Bull., No. 251, pp. 121-122, 2 pls., 1924.

In 1883, one year after his brother had entered, Gilbert came to Cornell taking a general course, and was graduated in 1886 with a Ph.B. During the graduation year at Cornell he roomed in White Hall with Seth D. Meek, who later became an authority on fish.

In the same class with Harris were Robert T. Hill and David White. In answer to the questionnaire of the Class of '86 as to their "Future occupation", Hill wrote "man and science", White put down, "naturalist", and Harris replied "undecided". It was the purchase of Dana's "Manual of Geology" in a book store in Ithaca which stimulated Harris to take graduate work in geology at Cornell and thereby determined his future career.

Even had it not been for this chance purchase, the "undecided" student would most certainly have decided to pursue some one of the natural sciences—probably botany. His high school graduation essay entitled "Nature's Pleasures" reflects the interest in nature which he shared with his brother. Little homemade note books (the unprinted margins of newspapers often serving for pages) filled with their boyish records and drawings of plants and animals, not only observed but studied, give further evidence of their keen delight in outdoor life and living. Both boys considered themselves fortunate to have been farm-born, although Gilbert was always to regret that because of this environment he did not have early opportunity for learning foreign languages. This was a lack which he continued to try to remedy from college days into his last years. At one time he even took a course in Sanskrit. He always advised his students to acquire as early and as wide a knowledge of modern languages as possible, with emphasis upon Spanish.

After a year of work under Henry Shaler Williams at Cornell, with Charles S. Prosser as assistant, Harris joined the Arkansas Geological Survey in 1888. John C. Branner (botanist-geologist) was State Geologist and Frederick W. Simonds, an assistant. Both had been trained under Charles F. Hartt, stimulating teacher and brilliant scientist, who initiated geological work at Cornell. The first assignment for Harris on the Arkansas Geological Survey was in connection with geological work in Washington County, assisting Simonds in the preparation of a map and report of that county. The report was published in 1891 as volume IV of the Annual Report of 1888 of the Arkansas Geological Survey by J. C. Branner. Chapter XVIII on "The Fayetteville-Huntsville Section" was by Harris.

In 1889, Gilbert Harris joined the United States Geological Survey where he worked under the auspices of the Paleozoic Division.[3] Some of the detailed work of the first of his five papers on Paleozoic rocks was done during that interval. Later he was transferred to the Cenozoic Division where he was assistant to William H. Dall in the Smithsonian Institution.

By means of cooperation between the United States Geological Survey and the Arkansas Geological Survey, Branner (Director) succeeded in obtaining the help of geologists regularly employed by the Federal Survey. Harris was delegated the task of delineating the areal distribution and subdivisions of the Tertiary of Arkansas. The winter of 1891-1892 and the fall of 1892 were spent by him in Arkansas.[4] The report of his work was published in 1894. The area examined in Arkansas was that south of the Arkansas River to the Louisiana line. The report reviewed the Cretaceous-Tertiary boundary, determined the stages of the Eocene present, described and illustrated many new species from the beds, and included a geologic map of "southern Arkansas and adjacent regions".

The chief new findings were the greater area of the Cretaceous to the northeast, beds which had been identified as Cretaceous were proven to be Eocene, the age of previously assigned Tertiary sediments was correctly referred to the Cretaceous, and the Midway (Paleocene) was found to be the oldest Tertiary in the state. Because of its "persistent nature, ... from Georgia to western Texas" (1894, p.8) and its lithologic and paleontologic differences with the deposits of the following stage, Harris recommended that the Midway be given coordinate rank with the "Lignitic" [Wilcox (Sabine)]. According to Gardener ("Midway group of Texas", 1933, p. 13) this was the first attempt to "recognize the significance and wide distribution" of the Midway. He noted the presence of Jackson Eocene fossils in the beds at White Bluff on the Arkansas River which he referred to "Upper Claiborne". In 1902 he assigned the beds to the Jackson. Harris did not return to the

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[3] Harris, G. D. *Geology of southwestern New York,* Amer. Geol., vol. VII, No. 3, p. 173, 1891.

[4] Harris, G. D. *The Tertiary Geology of Southern Arkansas,* Ann. Rept. Geol. Geol. Sur. Arkansas for 1892, vol. II, p. 6, 1894.

Arkansas Tertiary section until 1937, where on Crow Creek, near Forrest City, he discovered a vertebra of *Basilosaurus cetoides* (Owen), the only zeuglodont bone so far found in Arkansas.[5]

The rigors of the physical conditions under which the work of the early Arkansas Geological Survey was done had ill effects on Harris physically and left a lasting impression as to the care and conditions under which geologists should work. Some of the less hardy neophytes did not survive.

On December 29, 1890, Gilbert Harris married Clara Stoneman of Chautauqua County, New York.

While it was a school friend's joke that he was first attracted by the large stand of primeval pines on her family's acres rather than by their pretty daughter, the joke showed early recognition of his life-long fondness for trees. He was never to own a plot of ground which he did not straightway plant, often going to considerable trouble to do so. On occasion, even neighbors wakened to find on their premises a maple or a spruce which had not been there the night before, and as for those old Chautauqua pines which vanished long ago, they were replaced by hardwood and softwood seedlings in what he envisioned as "The New Forest". The evergreens are now of Christmas tree size.

But there was no opportunity for tree planting where the young couple made their first home in Washington, D. C. The "home" consisted of one room under the mansard roof of a house on 16th Street. The birth of a daughter (Rebecca Stoneman Harris) necessitated a move into larger quarters while her father was employed on the federal geological survey and during the following interval until 1894 when he joined the geological staff of Cornell University.

The first of three Harris homes in Ithaca was on Eddy Street, where the then bachelor Adam Capen Gill (Mineralogy and Petrology) was a frequent visitor. Around the corner, on Seneca Street, the Ralph S. Tarrs (Physical Geography), also newly arrived, were near neighbors. The three men were to have their offices and hold their classes in "old McGraw" until the end of their teaching careers. Professor Tarr died in 1912.

In 1911, the Harrises completed a large home (now 126 Kelvin Place) in what was at the time open field. Much of the work of building was that of his own hands, and most of the lumber used in construction came from the Stoneman farm woods. The choice of location was chiefly made because Dr. and Mrs. Gill were already living in a similar three-story home on an opposite block. The two families enjoyed an intimate and cordial neighborliness until 1932, when on August 14th Professor Harris was deeply saddened by the loss of his beloved wife. She had been a close and wise companion and, although an invalid for several years, her going was a shock to the family. The sudden death of his best friend, Dr. Gill, which occurred in November of the same year, so sharpened his sense of loss that it might have proved overwhelming had it not been for his work and the new venture he was contemplating.

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[5] Christmas Greetings, Paleontological Research Institution, 1938; Palmer, K. V. W.: *Basilosaurus in Arkansas*, Amer. Assoc. Pet. Geol., Bull., vol. 23, No. 8, pp. 1228-1229, 1939.

While associated with the Smithsonian Institution working under Dall, Harris continued his career and acquired the fundamental knowledge of the eastern and southern North American Cenozoic stratigraphy and paleontology. He gained first hand information through examination of the Survey's collections and those in the Academy of Natural Sciences in Philadelphia. He familiarized himself with the rare and basic literature, particularly that of Timothy A. Conrad, in relation to sections and fossils. Under the auspices of the United States Geological Survey in April, 1891, and May and June, 1892, he examined and differentiated the zones along the Calvert Cliffs, Maryland. He was accompanied during the last period by Frank Burns of the Smithsonian Institution, a skilled and energetic fossil collector. The results were published (1893) as "The Tertiary Geology of the Calvert Cliffs, Maryland". In 1914 Harris returned to the Chesapeake area by gasoline launch from Ithaca, New York, with seven of his students.[6] A second trip with students was made in 1915 by the same means.[7] The collections from these expeditions swelled the Cenozoic stores at Cornell. They were the source of extensive study of the Miocene fossils by Axel Olsson which resulted in three papers by him published in Bulletins of American Paleontology.[8] From those trips Ernest R. Smith's interest in the Pliocene and Pleistocene was stimulated, an interest[9] which was carried on until his death (1952). Lois M. Schoonover (Mrs. Louis Kent) a "Harris scholar" at Cornell University in 1934-36, later did a "Stratigraphic Study of the Mollusks of the Calvert and Choptank formations of Southern Maryland" (1936-40) for partial fulfillment of requirements for her doctor's degree at Bryn Mawr College, and it was appropriately published in the Bulletins of American Paleontology (vol. 25, No. 94B, 1941).

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[6] L. G. Grinnell, V. E. Monnette, A. A. Olsson, K. P. Schmidt, E. R. Smith, H. R Sunbal, and P. Wong

[7] C. P. Alexander, A. A. Olsson, K. P. Schmidt, E. R. Smith, B. Taylor and T. Thompson. See Power Boating, May, 1916 List of names furnished by A. A. Olsson of the party.

[8] Bulletins 24, 27, and 28 of volume 5, 1914, 1916, 1917.

[9] See bibliography in *Memorial* by J. C. Maxwell, Geol. Soc. America, Proc. for 1952, pp. 139-141, 1953.

In 1890-91 Dall and Harris were assigned the preparation of a memoir on the Neocene of the United States by the Director of the United States Geological Survey, J. W. Powell, with G. K. Gilbert, geologist-in-charge. This was fifth of a series of "Correlation Papers" which had been published by the Survey on summarizing the existing knowledge. The "Carboniferous" and "Devonian" by H. S. Williams (U.S. Geol. Surv. Bull. 80), "Cambrian" by C. D. Walcott (Bull. 81), "Cretaceous" by C. A. White (Bull. 82), and "Eocene" by W. B. Clark (Bull. 83) preceded the Neocene work (Bull. 84).[10] Harris was responsible in the work of the Neocene paper for searching the literature, compiling the list of formations and the discussion of the Interior Region. All had been done by experts in the special formations and the reports embodied original as well as compiled research.

In 1892, as Harris wrote in 1919,[11] curtailment in the affairs of the federal survey necessitated employment elsewhere of the younger members of that organization. Through the recommendation of C. D. Walcott, then Chief Paleontologist, later secretary of the Smithsonian Institution, Harris obtained appointment as Tertiary paleontologist to the Geological Survey of Texas during 1892 and 1893 under E. T. Dumble, State Geologist. Many Texas Tertiary fossils had been obtained and deposited in the Museum at Austin, Texas. With the exception of molluscan species described by Heilprin and Gabb, the greater number remained unstudied. Harris spent the major portion of his time examining the Texas material, comparing with types in Washington, D. C., and Philadelphia, and collecting en route at the classic localities of Claiborne Bluff, Black Bluff and Midway in Alabama, Vicksburg and Jackson in Mississippi. The result was a monograph of about 400 pages and 34 plates. The illustrations had been done by that master artist Dr. J. C. McConnell and a few by Harris. Lack of funds at the time prevented the publication of the manuscript. Descriptions of the new species, with a brief statement as to the Eocene stages in Texas, were published in 1895 in the Proceedings of the Academy of Natural Sciences of Philadelphia. Stratigraphic points were included in an article by Dumble in the Journal of Geology (vol. 2, 1894, p. 549). Kennedy,[12] in a detailed stratigraphic paper on the Eocene Tertiary east of the Brazos River, gave the lists of Harris's fossil determinations from the unpublished manuscript, including those which were later published and *nomina nuda.* The printing of the latter was an example of poor practice for it allowed names with no status to be inserted into literature, a procedure which always causes confusion.

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[10] U. S. Geol. Surv., Bull. 84, 349 pp. 3 pls., 1892.

[11] Bull. Amer. Paleont., vol VI, No 31, p. 3, 1919.

[12] Kennedy, Wm.: *The Eocene Tertiary of Texas east of the Brazos River,* Acad. Nat. Sci., Philadelphia, Proc., pp. 89-160, 1895.

An outline of what the Texas monograph consisted was published in Bulletins of American Paleontology, volume 1, Number 3, 1895, with an indication as to what portions had been printed. The Bulletin was on the "Neocene Mollusca of Texas or Fossils from the Deep Well at Galveston", and was a condensation of Part 3 of the original manuscript. It contained notes on the fossils from the Galveston well including about 20 new names. Up to that date "no other marine Neocene fossils" were "known from the Gulf west of Mississippi". Just previous (1891) to Harris's association with the Geological Survey of Texas, a deep well (3070 ft.) had been bored at Galveston, Texas. J. A. Singley, delegated by Dumble, had carefully obtained samples, fossils and information from the boring. Harris examined the fossils and reported on them in the Fourth Annual Report for 1892, of the Geological Survey of Texas, 1893, as well as with Dumble in American Journal of Science, volume XLVI, 1893. The significance and possibilities of what deep boring would reveal in subsurface geology was appreciated by Dumble and Harris in 1893. Dumble wrote, "The results of the investigation add a most important chapter to our knowledge of the history of the formation of the Gulf coast, and furnish a section for reference and comparison which could have been obtained in no other way." (1893, *ibid,* p. 41.)

Harris reiterated the same thoughts when in his Presidential address to the Paleontological Society of America December 30, 1936 (Bull. Geol. Soc. Amer., vol. 48, 1937) he stated, "I always feel that the sinking of the Galveston deep-water well in 1890 was of great moment in our coastal Tertiary studies. The method of rotary drilling had now shown its capability of penetrating soft beds to a depth of 3000 feet, at least, and by proper attention in collecting samples, could give a trustworthy record of the whole depth. Again, by this method of deep drilling the great thickness of our Gulf Coast Tertiary was demonstrated."

In the winter term of 1926-27, Professor Harris returned to Texas as Visiting Professor of Paleontological Geology in the graduate school of the University of Texas, and as a colleague of a former student of his, Professor Francis L. Whitney of the Geology Department.

While working at the Smithsonian, Harris realized the handicap to serious Tertiary students caused by the lack of copies of original fundamental paleontologic works of the American Tertiary authors such as Conrad, Lea and Gabb. He wrote in 1893, "He who would become versed in the marine Tertiary geology and paleontology of this country must first of all have a thorough understanding of Conrad's FOSSIL SHELLS OF THE TERTIARY FORMATIONS OF NORTH AMERICA: it marks the beginning of systematic research into this period of our continent's history."

To remedy such a serious lack, Harris compiled careful statistics from the existing copies of Conrad's edition as to original typography and exact dates of publication of the separate numbers of the "Fossil Shells". In 1893 he republished 225 copies of the text and 200 copies of the plates of that important work. It was this reprint which made the descriptions and figures of Conrad's Eocene fossils available to the students of the twentieth century, and linked Harris's name with that of the Nestor of American Tertiary fossils. It was truly appropriate for H. E. Wheeler in 1935,[13] when writing his historic account of Conrad, to dedicate the book to Gilbert Harris and to include his portrait. The same engraving is used as the frontispiece to this memorial.

The success of that republication venture and the satisfaction derived from the project, stimulated Harris to found the paleontological series, Bulletins of American Paleontology. In that series he initiated the policy of reprinting a few rare and needed paleontological papers. As a result, the papers of Thomas Say (1819-1825) in 1896, of Robert John Lechmere Guppy (1865-1913) in 1921 and in 1929[14] Conrad's Jackson Eocene fossils (1854) were republished.

Prior to 1895, Harris spent time in James D. Dana's office in New Haven, Connecticut, writing the "Marine Tertiary" for the Fourth Edition of Dana's "Manual of Geology". A number of the illustrations of Tertiary Mollusca were beautifully executed drawings of his own. He was the last, with the exception of T. W. Stanton (now 93) of the collaborators with Dana on that classic.

After his return to Washington, D. C., from work on the Texas Geological Survey, and while working on his own fossils in the Smithsonian, he was approached by Jacob Gould Schurman, President of

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[13] Wheeler, H. E.: *Timothy Abbott Conrad,* Bull. Amer. Paleont., vol. XXIII, No. 77, 151 pp., 27 pls., 1935.

[14] Bull. Amer. Paleont., vol. I, No. 5, 1896 (Say); vol. VIII, No. 35, 1921 (Guppy); vol. XXIV, No. 86, 1939 (Conrad).

Cornell University, with a view to Harris joining the faculty of that institution. In 1894 he went as Assistant Professor of paleontology and stratigraphic geology. He became Professor in 1909 and after 41 years of teaching there, retired as Emeritus on October 2, 1934, on his 70th birthday. Before beginning his teaching Harris went to France and England to familiarize himself with and make collections from the type Eocene localities of those regions. As a result of friendship with the French paleontologists and geologists, he was elected to membership in the Société Géologique de France. His teaching thereafter was savored with the influence of that contact and he frequently proposed his interested students as members to the French geological society.

The need for a means of the publication of paleontological papers in 1895 was acute. The study of the southern Tertiaries was a fertile field for the delineation of new forms. Following the original work of T. A. Conrad (1832-1860)[15] and the Leas, I. and H. C. (1833, 1848), T. H. Aldrich (1885-1932) and O. Meyer (1884-1887) carried the torch in behalf of the molluscan fossils of Alabama and Mississippi. Wm. Gabb (1860), A. Heilprin (1891), and Harris (1895) pioneered in Texas. W. H. Dall was writing his monumental Tertiary work in the Transactions of the Wagner Free Institute of Science (1890-1903), a comprehensive series of monographs presenting a galaxy of forms from the Pacific Coast through the West Indies. Dall particularly specialized in the later Tertiaries so that the wealth of new forms in the light of more refined stratigraphic observations of the Mississippi Embayment area was untouched. This was true in spite of the elaborate monograph (316 pp., 46 pls., quarto) of A. de Gregorio (1890) in Palermo of the fossils from a barrel of the Gosport sand or of the lesser tome of M. Cossmann (1893, 51 pp., 2 pls.) in Paris, on the fossils from the same formation.

Harris, in 1895, was fresh from studies in the Eocene of the Paris and London basins. Because of accumulative experiences, he was the recognized authority on the Eocene of the eastern and southern states, and he had a wealth of new field and fossil data to present to the paleontological world. He had spent the time and labor of preparing one large manuscript. This was lost, as far as total publication was concerned, because of lack of funds, and he had made a success of one printing venture. These were the conditions which spurred him to strike out on a private enterprise of publishing the series which he titled Bulletins of American Paleontology. They were first printed on his own platen press in the Geology Department, McGraw Hall, at Cornell University. The first number was appropriately written by himself on "Claiborne Fossils." The second number by T. H. Aldrich on "New or Little Known Tertiary Mollusca from Alabama and Texas" was equally suitable. Aldrich continued to publish at intervals in the Bulletins until 1921. Although the two authorities on the southern Eocene, Harris and Aldrich, carried on correspondence to their mutual help and interest, they never met. In 1919, Harris dedicated his treatise of the "Pelecypoda of the St. Maurice and Claiborne Stages" to his long-time friend and scientific colleague, "Hon. Truman H. Aldrich, who has continuously maintained that true Conradian love for our Eocene Mollusca from the last days of that forgetful dreamer on into the Twentieth Century this work is most respectfully dedicated—". The word "affectionately" might well have been added.

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[15] Dates following the names refer to publications.

The first two numbers of the Bulletins were published under the auspices of Harris and Stoneman. The following numbers were by Harris Company until, in 1932, volume XX bore the emblem of the Paleontological Research Institution. Though Harris, as before, continued the printing of the papers on his own presses, he conveyed in 1932 the ownership of his publications to his newly founded organization.

In August, 1895 Harris rearranged and catalogued the Isaac Lea Tertiary [marine] Collection at the Academy of Natural Sciences. Due to the controversy over the priority of names of Conrad and Lea of Claiborne species this provided important information as to the original material available in connection with those names.

Edward M. Kindle, young geologist from Indiana, received his Master's degree in 1896 after studying, during the second year of Harris's teaching at Cornell, the relation of the Ithaca group to the faunas of the Portage and Chemung Devonian. This work, based on exhaustive collections carefully tabulated in the sections of the Ithaca group, was published by "the Professor" in the still infant series of the Bulletins of American Paleontology (No. 6, vol. II, 1896). This paper marked the beginning of the practice by Professor Harris of printing these and other original papers of his students. Such ready publication made it possible for them to secure an early place on the roster of original investigators and gained for their publisher their lasting loyalty and cooperation.

With financial help from the Trustees of Cornell University in 1895 and in 1896, Harris and W. S. Hubbard were able to further investigate Eocene sections, including collections of fossils, from western Tennessee to western Georgia. This material, together with collections made before and after, made possible the development of Harris's plan for thoroughly illustrating the fossils of the southern Tertiary from the Paleocene (Midway), group by group, from older to younger horizons. This project was one of the major contributions he made to the science of paleontology. The first of the monographs, "Midway Stage," illustrated by skilled drawings of 15 plates from his own pen, (Bull. Amer. Paleont., vol. I, No. 4, 165 pp., 17 pls., 1896) was a factor in breaking the ground for a clearer understanding of the true relation of the Midway and the Cretaceous. Besides noting the unconformity between the Cretaceous and the overlying Eocene [Paleocene] east of the Mississippi, the conclusions reached in the Midway monograph were summed up by Harris to H. S. Williams (Amer. Jour. Sci., vol. CLII, 4th ser., vol. II, p. 86):

"All of Gabb & Safford's 'Ripley Cretaceous' fossils from Hardeman Co., Tenn., are Eocene.

"The uppermost 100 ft. of Smith & Johnson's 'Cretaceous' section at Prairie Bluff is Eocene, as proven by an abundant and typical Eocene fauna.

"The beds at and to the south of Palmer's mill, Wilcox Co., Ala., referred to the 'Cretaceous' by Smith & Johnson (Bull. 43, U.S.G.S.) are all Eocene. Here, as on the Alabama River, they have their contact line 100 or more feet too high.

"*Enclimatoceras ulrichi,* instead of being confined to one calcareous bed, a few feet in thickness, is now known to occur in every important bed of the Midway stage in western Alabama, from the contact (Cret.-Eoc.) below to and including the Matthews landing horizon.

"The Chattahoochee River Midway limestones are the representatives of the whole Midway stage to the west, and are not the outgrowth of an insignificant rock in western Alabama."

The same general aim of completeness of description and illustration of the "Lignitic" lower Eocene (Wilcox [Sabine]) stratigraphy and paleontology was carried out in two Bulletins on that stage (vol. II, No. 9, 1897 and vol. III, No. 11, 1899). The illustrations of the fossils were drawn by Harris.

Extra teaching activities, field investigations with the Louisiana Geological Survey, and services in regard to publication of his paleontological series delayed the research and writing of the molluscan fauna of the mid-Eocene lower Claiborne and Gosport sand stages of the planned project until 1919. The "Pelecypoda of the St. Maurice and

Claiborne Stages," was published (Bull. Amer. Paleont., vol. VI) with only brief statement of the stages of the Gulf Eocene but with 59 plates of illustrations of the fossil Mollusca. The nomenclature of the species was not revised nor generic determinations differentiated in the light of modern or biologic usage, but he did depart from pen and ink sketches of fossils to photographic illustrations which are better, as he pointed out, to depict the real character of the specimens.

Increased activities other than his favorite research on the southern Eocene fossils further retarded his study and illustration of the mid-Eocene gastropods. Harris in 1925 asked the present writer to take over the project which he saw he would not have time to do. That investigation was carried on and published as number 32 of Bulletins of American Paleontology.[16] The work on the upper Eocene (Jackson) Mollusca was a joint project by Harris and Palmer. The study was based on material collected by Harris and A. C. Veatch on early expeditions to the various localities in Louisiana, Mississippi, and Alabama, collections made by Harris, R. H. Flower, and K. V. W. Palmer in 1935, and by Harris and the Palmers (K. V. W. & E. L.) from Arkansas through Mississippi area to North Carolina in 1938 under the auspices of a Geological Society of America grant from the Penrose Fund, and by Harris alone in 1940. The combined work was published as Number 117, Bulletins of American Paleontology. The investigations were continued by those authors on the mollusks from the Ocala limestone, Jackson Eocene, of Florida. Part of the material was obtained during an extended collecting trip in 1946. The last paper which Harris published (1951) consisted of notes on Ocala bivalves.

In 1898 until 1909 in addition to teaching at Cornell, Professor Harris served as geologist-in-charge to the Geological Survey of Louisiana. By teaching in summer he was able to spend part of the winter period, mid-December to late March, in Louisiana, the remainder of the year at Cornell working up the reports for the survey. Arthur C. Veatch, able and enthusiastic student of Harris, was assistant on the Louisiana Geological Survey, as well as instructor at Cornell. In 1898, Veatch spent the greater portion of the year in Louisiana. Their combined work formed the "Preliminary Report on The Geology of Louisiana" (1899). Besides the maps and discussion of general geology, the publication included special articles among which were a detailed report on the "Five Islands" by Veatch, the illustrated "Cretaceous and Lower

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[16] Palmer, K. V. W. *The Clabornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States.* Bull. Amer. Paleont., vol. VII, No. 32, 730 pp., 90 pls.

Eocene Faunas of Louisiana" by Harris and "The Establishment of Meridian Lines" by Harris. It was in the report of 1899 that Harris and Veatch first disproved the so-called Cretaceous "backbone of Louisiana" (p. 62) and asserted the existence of dome structure in the state.

In 1902 "The Report of the Geology of Louisiana" was the combined labor of Harris and his assistants A. C. Veatch and J. A. A. Pacheco during 1900, 1901 and 1902. About three months of each year were spent in Louisiana. Besides the fundamental papers and maps on the "Geology of the Mississippi Embayment" by Harris and "Salines of North Louisiana" by Veatch, the report contained the geology of those classic traverses by Veatch of the Sabine and Ouachita rivers.

Capt. A. F. Lucas's gusher at Spindle Top, Texas, on January 10, 1901, with its 3,593,113 barrels of oil, startled the petroleum world and as Harris (1908, p. 63) commented, it was the "Commencement of our education, regarding a new type of geological phenomena . . origin and method of development of dome structure". The impetus which this new development gave to geological work in the Louisiana-Texas area stimulated his writing of the Bulletin of the Geological Survey of Louisiana on "Rock Salt" assisted by Carlotta J. Maury and Leopold Reinecke. This and his work in cooperation with the United States Geological Survey which was published as Bulletin 429 of that organization, were pronounced in 1926 (DeGolyer; Spooner) the most comprehensive reports on salt domes. His theory of salt domes at one time was widely accepted.

In 1902 A. C. Veatch joined the United States Geological Survey, to prepare a report on the geology and underground water resources of Louisiana (Prof. Paper 46). Pacheco remained the able field man. L. Reinecke and F. L. Whitney, both students of Prof. Harris, became assistants on the Survey. John L. Rich, E. B. Hopkins, and students from Louisiana State University were part of the field investigators. In the late fall and early winter of 1908, Irving Perrine and Walter Hopper worked with Harris in the field on the oil and gas report (1909), the data of which were also incorporated in Bulletin 429 (U.S.G.S.) on oil and gas in Louisiana. The definition by Harris in 1907 (1908) and 1910 of the Sabine Uplift of northwestern Louisiana and northeastern Texas revealed one of the major structural factors of the southern coastal plain.

Besides the topographic and geologic mapping and the paleontologic studies combined in the work of the Geological Survey of Louisiana, special attention was paid to various phases of precise measurements as primal factors in structural deductions. His establishment, with the cooperation of the United States Coast and Geodetic Survey, of magnetic stations, meridian lines, self-recording tide gage and bench marks represents pioneer work and far-sighted planning as to the basic needs in the accumulation of geologic facts. His reports of 1905 (Bulletins 2 and 3) of the Louisiana Geological Survey contained the description of the method, stations and results of terrestrial magnetism and meridian line work and the same for his tide gage labor.

While he and his assistants were making a reputation by their pioneer geologic mapping, stratigraphic and paleontologic endeavors in Louisiana, Harris at this period was training students in field geology in the summer. His methods left with the participants a lasting impression of the superior benefits of such contacts over mere text-book teaching and aroused their admiration and loyalty for the teacher who inspired the work.

To expedite the problem of travel so that he could take his students far afield to observe geological features first hand, Professor Harris purchased, at intervals during the pre-automobile period, four gasoline launches. By their means, he conveyed summer students via the Erie Canal (1899-1909) to the Helderbergs and Lake Champlain, in 1914-1915 to Chesapeake Bay area, and up until 1920 historical geology classes on Cayuga Lake.

Harris and students on the *Ianthina,* Cayuga Lake
Ca. 1900

In 1899, five students, including H. F. Cleland and J. A. A. Pacheco composed the first geological excursion with Harris to eastern New York via the Erie Canal, in the launch "Ianthina". The following year fifteen members of the Cornell Summer School of Field Geology under his direction were transported by means of the "Ianthina" and a second, faster boat, the "Orthoceras" via the Erie Canal to the region of Trenton Falls, Little Falls, and the Helderberg Mountains. Among the group were H. F. Cleland, P. E. Raymond, A. C. Veatch, J. A. A. Pacheco, and L. B. Sage. Veatch and Cleland were assistants. The following year Cleland, Veatch, Raymond and Miss Sage instructed in the work. That year, with headquarters in the Helderbergs, there were 27 students, five of whom had been present the previous year. Fourteen of the group were women. The period was divided into two sections so that while one group worked in the Helderberg Mountains, the others made excursions to the Lake Champlain region, Becraft Mountain, and Trenton Falls. They camped in tents or slept on the boats, they cooperated in the campkeeping and shared the work of geologizing with the fun of the campfire and comradery. From the mapping and the fossil collecting four original papers were published in Bulletins of American Paleontology. Two were by Cleland on the "Calciferous" (Beekmantown) formation of the Mohawk Valley (Bulls. 13 and 18) and two by Raymond, one on the "Crown Point Section" (Bull. 13) and one on faunas from the Trenton limestone (Bull. 17).

The summer geological camp in the Helderbergs in 1904 included J. L. Rich, F. L. Whitney, L. Reinicke, and J. A. A. Pacheco who accompanied the Professor on his boat from Ithaca. Particular attention at this time was paid to the study of the Silurian-Devonian contact from the Helderberg Mountains to Cayuga Lake. Harris and the same four assistants continued the geologic work in the vicinity of Union Springs, Cayuga Lake, which death had prevented C. A. Tracy from completing. As a result of this research "The Helderberg Invasion of the Manlius" was published in Bulletins of American Paleontology (vol. IV, No. 19, 1904) and "Guide to the Geology of Union Springs". The latter was the third and last number of an "Elementary Natural History Series" published by Professor Harris.

Although Harris's major interest was not in the stratigraphy and paleontology of the Paleozoic rocks, he ever emphasized the ideal geologic setting of Cornell University, as well as that of the fine exposures and sequence of the Paleozoics in New York State, for teaching earth history. He was particularly anxious that some one of his students would carry on the investigation of the Mississippian-Devonian relationships of northeastern Pennsylvania and southwestern New York. His wish was fulfilled in the interest and energetic studies which Kenneth E. Caster carried on producing important contributions to a complicated stratigraphic problem and to the paleontologic studies (Bull. Amer. Paleont., Nos. 58, 71, and 75 [with Flower]).

By 1914-1915 Professor Harris had built at Ithaca a cabin launch, the "Ecphora". This was the boat which carried students to the Chesapeake region, and until 1920, took the Cornell students in historic geology to the fossiliferous Devonian outcrops on the shores of Cayuga Lake.

In 1920 Harris went to Trinidad on oil geology consultation. In 1924 he made a trip to Venezuela in the same capacity and continued as consultant until the thirties. Not only did he make large personal collections of fossils in Trinidad and Venezuela, but he promoted his students into geologic work in South America and the Caribbean region. There resulted a long series of paleontologic and stratigraphic publications in the Bulletins of American Paleontology and Palaeontographica Americana by Harris, C. J. Maury, Floyd and Helen Hodson, A. A. Olsson, N. E. Weisbord, R. A. Liddle, W. S. Cole, J. W. Wells, and K. V. W. Palmer.

His last foreign trip in the summer of 1928 was to north Germany as geologic adviser.

To provide a fire-proof building for the large and increasing collection of fossil invertebrate types, publication stock, and library and to insure the perpetuation of the two paleontological series he was fostering, Harris founded in 1932, the Paleontological Research Institution. This organization was chartered by the State of New York and governed by an elected Board of Trustees. To launch such an enterprise he transferred to the Institution land from his home lot, a building, collections, library, equipment, stock of publications and printing equipment. After retirement from teaching duties in 1934, his interest was dominated by the development of this institution. His time was divided between activities there and the surveying and real estate matters pertaining to his old home and his wife's family farm in Chautauqua County. He continued to operate his presses and in 1949, in his 85th year, had printed through No. 134 of the Bulletins of American Paleontology. His failing eyesight was an increasing handicap but until his last illness he spent long hours in photographing and compiling data on his favorite family of gastropods, the Turridae. He saw the housing of the research and publishing organization which he founded grow from that of a two-story, three-room depository, the "Cabina," to a building enlarged by two additions of three-story units to house the presses, photographic equipment, research rooms and storage space.

Photo E. L. Palmer

Paleontological Research Institution — 1953

Harris was a member of Phi Beta Kappa, Sigma Xi, Sigma Gamma Epsilon, Société Géologique de France, the Société Géologique Suisse, American Association for the Advancement of Science, a Fellow of the Geological Society of America and of the Paleontological Society of America, an Honorary member of the American Association of Petroleum Geologists, and Corresponding member of the Academy of Natural Sciences of Philadelphia. He was President of the Paleontological Society of America in 1936 and Vice--President of the Geological Society of America in 1937. He served as Life Trustee, Treasurer, 1932-1951, and Director, 1950-51, of the Paleontological Research Institution. One of the graduate fellowships given by Cornell University is named in his honor (1953).

Professor Harris is survived by his daughter, Rebecca Stoneman Harris, who resides at the home. She is a Life Trustee and Secretary-Treasurer of the Paleontological Research Institution.

Gilbert Dennison Harris was a tireless worker mentally and physically. He was interested in politics and world affairs, but his alert mind was chiefly concerned in developing geologic science, particularly paleontology. His predominant scientific activities and interests were balanced with a wholesome sense of humor. He continually thought to provide opportunities for his students' training. Although much thought and effort were given to the preparing of his lectures, they were not clearly or appealingly delivered. But those students who were in direct contact, either in the field or laboratory, with his stimulating influence and training, responded with a lasting loyalty, confidence and the inspiration to carry on. Each remembers some anecdote which illustrated his genial, whimsical and helpful nature. He was determined but kind. He had no interest for the indifferent student but for those who were capable and energetic, he provided opportunity and stimulation to encourage their interest in geological subjects.

To honor Gilbert Dennison Harris for his basic efforts of original field studies and research, for his training of students who have also contributed to geologic investigations, for the establishment of the series of fundamental paleontological literature and for the founding of an institution for the preservation and dissemination of paleontological material, this thirty-fifth volume of the Bulletins of American Paleontology is dedicated to his memory by the members of the Paleontological Research Institution, who to this memorial affectionately subscribe.

Katherine V. W. Palmer

Paleontological Research Institution
Ithaca, New York
September 15, 1953.

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CRITERIA FOR THE RECOGNITION OF CERTAIN ASSUMED CAMERINID GENERA

By

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December 24, 1953

Paleontological Research Institution
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CRITERIA FOR THE RECOGNITION OF CERTAIN ASSUMED CAMERINID GENERA[1]

W. Storrs Cole
Cornell University, Ithaca, N. Y.

ABSTRACT

The genera *Camerina, Miscellanea, Operculina, Operculinoides, and Pellatispirella* are discussed and typical specimens are illustrated. *Pellatispirella* is recognized as a valid genus and is transferred to the nonionids. *Operculinoides bermudezi* (D. K. Palmer) is reevaluated and new illustrations are given.

INTRODUCTION

The classification of the camerinids both at the generic and specific levels is not satisfactory. Recently, Grimsdale and Smout (1947, p. 15) stated that *Operculinoides* is a synonym of *Camerina.* Glaessner (1945, p. 175) wrote "Some species of *Operculinoides* occurring in the Miocene are not easily distinguishable from the latest striate *Camerina.*" Many other citations could be given to demonstrate the uncertainty between the two genera mentioned, as well as many of the other genera assigned to this family.

In the study of a camerinid species found in certain wells in Georgia[2] it was necessary to decide to what genus these specimens should be assigned. Various authors have placed this species in the genera *Miscellanea, Ranikothalia,* and *Nummulites* (*Operculinoides*).

Moreover, confusion exists in current concepts of many of the species. Several specific names have been assigned to a well-known and thoroughly described Paleocene species which is widely distributed in the Caribbean region. This species has appeared in the literature as *Operculina bermudezi* D. K. Palmer, *Pellatispirella antillea* Hanzawa, *Camerina pellatispiroides* Barker, *Miscellanea antillea* (Hanzawa), and *Miscellanea tobleri* Vaughan and Cole.

Therefore, several of the most disputed genera are discussed and new information is presented on the species most commonly called *Miscellanea antillea* (Hanzawa).

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[1] This paper is a partial outgrowth of a general program of studies on the larger Foraminifera for the U. S. Geological Survey.

[2] This species is described and illustrated in the following Bulletin, Bull. Amer. Paleont., vol. 35, No. 148, 1953.

KEY TO GENERA

The genera discussed can be separated by means of the following key:

A. Spiral sheet with numerous pillar-like structures or pectinations
  1. Without a marginal cord .... *Pellatispirella*
  2. With a modified marginal cord which appears as a large, nearly circular canal .... *Miscellanea*

B. Spiral sheet entire or nearly so; marginal cord typical and well developed
  1. Completely involute
    a. Chambers of the median section always showing a marked increase in height .... *Operculinoides*
    b. Chambers of the median section increasing gradually in height, never with a marked increase in height .... *Camerina*
  2. Evolute, normally compressed
    a. Chambers of the median section always showing a marked increase in height .... *Operculina*
    b. Chambers in the median section increasing gradually in height .... *Assilina*

DESCRIPTION OF GENERA

Genus **PELLATISPIRELLA** Hanzawa, 1937

Plate 1, figures 1, 2

Pellatispirella Hanzawa, type species *Camerina matleyi* Vaughan, 1929.

This genus is characterized by possessing coarse vertical canals in the spiral sheet, not only in the axial region, but throughout, so that in transverse section the spiral sheet on its outer edge has a series of knoblike projections. The marginal cord is lacking. Apertures are a series of small, round openings at the base of the septal face. The embryonic apparatus consists of a single large, spherical chamber.

The structure of the test is similar to that of *Elphidium,* and the two genera are closely related.

Two American species are known:

P. *matleyi* (Vaughan), 1929.
nassauensis (Applin and Jordan), 1945.

Remarks.—After Hanzawa (1937, p. 114) described the genus *Pellatispirella*, Vaughan and Cole (1941, p. 32) reviewed this genus and stated "The essential structure of the type species of *Miscellanea* and *Pellatispirella* is identical." Later, Vaughan (1945, p. 25) reiterated this view.

Miss Caudri (1944, p. 21) retained the type species of *Pellatispirella*, *Camerina matleyi* Vaughan, in the genus *Miscellanea*, following Vaughan and Cole. However, the second species which Hanzawa originally described in the genus *Pellatispirella*, *P. antillea*, and which was placed by Vaughan and Cole in *Miscellanea*, was transferred to the genus *Ranikothalia* (Caudri, 1944, p. 17), the type species of which was given as *Nummulites nuttalli* Davies.

Cole (1947, p. 13) wrote "Although the writer agreed with Vaughan earlier in placing all the species assigned by Hanzawa (1937) to the genus *Pellatispirella* under *Miscellanea*, it would seem desirable from this study to reassign the species *matleyi* to *Pellatispirella*, but place the other species under *Miscellanea*. Moreover, *Pellatispirella* probably does not represent a genus of the family Camerinidae, but one of the family Nonionidae."

Mrs. de Cizancourt (1948*a*, p. 664) in a study of Nicaraguan specimens concluded that the type species of *Pellatispirella* and *Miscellanea* have the same structure.

Although she (p. 667) gave a correct synonymy of *Pellatispirella antillea* Hanzawa, she referred this species to *Nummulites* (*Nummulites*). At the same time she assigned *Pellatispirella* to the genus *Miscellanea*. However, below the synonymy of *Miscellanea* on page 667 she described a species as *Miscellanea antillea* (Hanzawa), the illustrations (pl. 23, figs. 4, 7, 12) of which demonstrate that it is *Pellatispirella matleyi* (Vaughan). In all probability Mrs. de Cizancourt meant to write *matleyi* for *antillea* and Vaughan for Hanzawa. If *Miscellanea antillea* Hanzawa is changed to *Miscellanea matleyi* (Vaughan) on page 667, 668, and 674, the text, the figures and explanation of plates are consistent with one another. As they are written, they conflict.

Unfortunately, Sigal in "Traite de Paleontologie" (1952) copied Mrs. de Cizancourt's (1948a, pl. 23, figs. 1, 2, 4) figures of specimens which are undoubtedly *Pellatispirella* as examples of *Miscellanea*. Moreover, he showed as *M. antillea* (Hanzawa) the specimen of *P. matleyi* which Mrs. de Cizancourt incorrectly named *M. antillea* (Hanzawa).

The two species described by Mrs. de Cizancourt (1948a) as *M. hedbergi* and *M. nicaraguana* are synonyms of *P. matleyi* (Vaughan) as there are no features which would serve to separate them from *P. matleyi.*

Miscellanea nassauensis Applin and Jordan (1945, p. 139) has a spiral lamina which shows pectinations similar to those found in *Pellatispirella matleyi.* Reference should be made to the transverse sections of *P. nassauensis* figured by Cole (1947, pl. 4). A small segment of the spiral lamina of one of these specimens (Cole, pl. 4, fig. 5) is illustrated, greatly enlarged, as figure 2, Plate 1 of this article to show the details of the wall structure.

Genus **MISCELLANEA**, Pfender, 1934

Plate 1, figures 3, 4

Miscellanea Pfender, type species *Nummulites miscella* d'Archiac and Haime, 1855.

This genus is characterized by a granulated spiral sheet. These granules appear in transverse sections as pillar-like structures which are especially well developed over the embryonic apparatus and at the acute periphery of the test. A typical marginal cord, however, is not present. The granules appear prominently in the spiral wall in median sections, showing as small, round areas of clear shell material.

Normally, a large canal shows in transverse sections in the area where the marginal cord should be developed. Vaughan (1945, p. 24) mentions the presence of this canal, but stated "I am not convinced of the taxonomic significance of this feature".

Davies (1937, p. 41) showed the details of the structure of *Miscellanea* in a clear diagram. *Miscellanea* differs from *Pellatispirella* in its much larger size, in the possession of a bilocular embryonic apparatus, in the development of a less disintegrated spiral sheet and in the juncture of the chamber walls as they join the revolving wall. The chamber walls in *Miscellanea* as viewed in accurately centered median sections are separated from the revolving wall by a marked opening (see Vaughan and Cole, 1941, pl. 5, fig. 5). In *Pellatispirella* the chamber walls join the revolving wall so that a slitlike aperture cannot be present between the chambers (see Vaughan, 1929, pl. 39, fig. 5). *Miscellanea,* also, possesses a large circular canal which appears in the area of the marginal cord (Pl. 1, fig. 3) and represents a modification of the marginal cord. *Pellatispirella* is without any suggestion of a marginal cord (Pl. 1, fig. 1).

Miscellanea is clearly a camerinid, whereas *Pellatispirella* shows affinities with the nonionids, inasmuch as its wall structure and type of aperture are similar to those of *Elphidium* (see Cole, 1947, pl. 4, fig. 13).

No American species are known.

Genus **CAMERINA**[3] Bruguière, 1792

Plate 1, figure 13; plate 2, figures 7-10

1792. *Camerina* Bruguière, type species *Camerina laevigata* Bruguière.

The features which characterize well-developed representatives of this genus are a strong, distinct marginal cord, numerous volutions and a slow increase in the height of the whorls, or gerontically a decrease in height of the final whorl. The aperture is a curved slit at the base of the last septal face.

Small *Camerina* intergrade with *Operculinoides,* but the latter always shows in median sections an increase in height of the chambers of the final whorl.

There are few American representatives of this genus, all of which are confined to the upper Eocene.

Certain typical species follow:

Camerina striatoreticulata (L. Rutten)=*C. petri* M. G. Rutten; *C. rutteni* (Cizancourt)
malbertii M. G. Rutten=*C. dorotheae* (Cizancourt)
macgillavryi M. G. Rutten
vanderstoki (Rutten and Vermunt)

Remarks.—Grimsdale and Smout (1947, p. 14) have questioned the traditional description of the aperture of *Camerina* as "aperture simple, at the base of the apertural face, median." From a study of *Camerina planata* (Lamarck) and other species they conclude that the aperture is "a row of pore-like openings along the junction of the septum with the previous whorl." Glaessner (1945, p. 175) described the aperture of *Camerina* in these terms, "Aperture at the base of the septum, externally rarely clearly visible in complete test."

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[3] This generic name is retained notwithstanding the recent substitution of *Nummulites* for *Camerina* (see Opinion 192, International Commission on Zoological Nomenclature, 1945) as *Nummulites* is without question a junior synonym of *Camerina.* Vaughan (1945, p. 23), was of the same opinion when he wrote "—*Camerina,* of which *Nummulites* is a synonym." In a letter to me dated 30 September 1947 he restated this opinion in positive terms.

Carpenter (1862, pl. 18, fig. 2) showed the aperture to be a simple, median, slitlike opening at the base of the apertural face. However, he showed large pores in the marginal cord just below the slitlike aperture.

Although the specimens of *Camerina* available for this study were not sufficiently well preserved to demonstrate the apertural characteristics in entire specimens, it was possible to observe the features of the aperture in transverse section. Two transverse sections showing the aperture are illustrated as figures 8, 10, Plate 2. In both of these the aperture appears as illustrated by Carpenter. Therefore, it may be that Grimsdale and Smout observed the pores in the marginal cord which may be secondary apertures rather than the true, slitlike aperture at the base of the septal face.

Genus **OPERCULINOIDES** Hanzawa, 1935

Plate 1, figures 5-12; plate 2, figures 2-6

1935. *Operculinoides* Hanzawa, type species *Nummulites willcoxi* Heilprin, 1882.

1937. *Pellatispirella* Hanzawa (part).
1941. *Miscellanea* Vaughan and Cole, not *Miscellanea* Pfender, 1934.
1944. *Ranikothalia* Caudri.
1945. *Miscellanea* Vaughan, not *Miscellanea* Pfender, 1934.

Hanzawa (1937, p. 114) proposed the genus *Pellatispirella* and placed in this genus two species, *"Camerina" matleyi* Vaughan (1929, pp. 376, 377, pl. 39, figs. 2-7) and *P. antillea,* a new species. He designated *"C." matleyi* the type species.

Vaughan and Cole (1941, p. 32) restudied these and other species, including specimens from the Kohat District, India, which represented the genus *Miscellanea* Pfender. They concluded that *Pellatispirella* was a synonym of *Miscellanea.*

Later, Miss Caudri (1944, pp. 367-371) described the genus *Ranikothalia* in which she placed all the American species previously assigned by Vaughan and Cole to *Miscellanea* with the exception of *"Camerina" matleyi* which she retained in the genus *Miscellanea.*

Vaughan (1945, p. 23) restudied the American species assigned to *Pellatispirella, Miscellanea* and *Ranikothalia* and decided again that they should be included in *Miscellanea.* Davies (1949, p. 113), however, accepted the classification proposed by Miss Caudri.

Mrs. de Cizancourt (1948b, p. 11) concluded that the genus *Ranikothalia* was superfluous on valid grounds. However, she would combine such genera as *Operculina, Operculinoides,* and *Operculinella* with *Camerina,* giving them subgeneric rank. To this combination the writer does not agree.

Operculina and Operculinoides are distinct genera. For example, *Operculina* with its compressed, evolute test is sufficiently distinct from *Camerina* with its lenticular, involute test to warrant generic separation. However, *Operculinella* is not a valid subgenus as its broadly flaring, complanate border is a gerontic development. Hanzawa (1939, p. 229) stated concerning *Operculinella cumingii* "This species is involute in young and later becomes evolute as is usual in *Operculina,* from which it is hardly distinguishable, except by having strongly curved septa in the last whorl."
Curvature of the septa is a specific rather than a generic character. Median and transverse sections of *O. cumingii* cannot be distinguished from similar sections of various species assigned to *Operculinoides.*

The genus *Operculinoides* was proposed by Hanzawa (1935, p. 18) for North, South and Central American specimens which "show peculiar characteristics intermediate between the typical *Operculina* and *Camerina* or *Assilina."*

Operculinoides differs from *Camerina* in developing a marked increase in the height of the chambers as observed in the median section. This may be followed by a gerontic slight decrease in height of the final chambers. In typical *Camerina* this increase in height does not occur. Moreover, in transverse section *Camerina* is always lenticular or compressed lenticular, whereas in *Operculinoides* the test may be lenticular (figs. 2, 6, Pl. 2), or it may be lenticular in the central portion beyond which occur compressed margins (fig. 5, pl. 2). Typical median sections of *Operculinoides* are shown by figures 11, 12, Plate 1.

Most of the American species of camerinids belong to this genus.

Remarks.—American species which were assigned formerly to *Miscellanea* and which are considered here to be *Operculinoides* uniformly possess a coarse marginal cord. At the beginning of this study it was thought that this structure might be of generic significance. However, the degree of development of the marginal cord is extremely variable in various species assigned without question to *Camerina*. This is demonstrated by figures 8-10, Plate 2.

Once this fact was appreciated, the marginal cords of a number of species which has been assigned previously to *Operculinoides* were examined. It was discovered in these specimens that the strength of the marginal cord varies from species to species. This is demonstrated by figures 2, 5, 6, Plate 2.

It is apparent, therefore, that the degree of coarseness and size of the marginal cord is a specific rather than a generic feature in both *Camerina* and *Operculinoides*.

The American species assigned first to *Miscellanea* and later to *Ranikothalia* possess a canal system, a marginal cord and wall structure of the spiral lamina which is in every respect comparable to that of *Operculinoides*. Any minor differences, such as the coarseness of the marginal cord, is in degree rather than in kind or in development of a new structure.

Genus **OPERCULINA** d'Orbigny, 1826

Plate 2, figure 1

1826. *Operculina* d'Orbigny, type species *Lenticulites complanata* Defrance, 1822.

1918. *Operculinella* Yabe.

The test is compressed, evolute with the chambers normally increasing markedly in height. This genus is too well known to warrant detailed analysis. Reference should be made to the statements given under *Operculinoides*.

Few American species are known of which *O. mariannensis* Vaughan is the most typical.

DESCRIPTION OF SPECIES

Family **Camerinidae**

Genus **Operculinoides** Hanzawa, 1935

Operculinoides bermudezi (D. K. Palmer) Pl. 1, figs 5-7; Pl. 3, figs. 2-12

1934. *Operculina bermudezi* D. K. Palmer, Mem. Soc. Cubana Hist. Nat., vol. 8, pp. 238-240, pl. 12, figs. 3, 6-9.

1937. *Pellatispirella antillea* Hanzawa, Jour. Paleont., vol. 11, p. 116, pl. 28, figs 8-10; pl. 21, fig. 1.

1939. *Camerina pellatispiroides* Barker, U. S. Nat. Mus., Proc., vol. 86, No. 3052, pp. 325, 326, pl. 20, fig. 10; pl. 22, fig. 4.

1941. *Miscellanea antillea* (Hanzawa), Vaughan and Cole, Geol. Soc. Amer., Sp. Paper 30, pp. 33-35, pl. 4, figs. 1-4; pl. 6, figs. 3, 3a.

1941. *Miscellanea tobleri* Vaughan and Cole, *ibid,* pp. 35, 36, pl. 4, figs. 5, 6, 7; pl. 7, fig. 1.

1944. *Ranikothalia antillea* (Hanzawa), Caudri, Bull. Amer. Paleont., vol. 28, No. 114, p. 22, pl. 1, figs. 4, 5; pl. 3, fig. 15; pl. 4, fig. 21; pl. 5, figs. 23, 25.

1945. *Miscellanea antillea* (Hanzawa), Vaughan, Geol. Soc. Amer., Mem. 9, pp. 27-29, pl. 3; pl. 4, fig. 1.

1947. *Miscellanea antillea* (Hanzawa), Cole and Bermudez, Bull. Amer. Paleont., vol. 31, No. 125, pp. 195-196, pl. 2, figs 10, 11.

1950. *Nummulites* (*Nummulites*) *caraibensis* de Cizancourt in Thalmann, Contrib. Cushman Foundation Foram. Res., vol. 1, pts. 3, 4, p. 43.

Through the kindness of the late Mrs. D. K. Palmer the author received a generous sample from the type locality of *O. bermudezi.* This sample came from the "cut on the Carretera Central under the railroad bridge at Central San Antonio 2 kilometers west of Madruga, Havana Province (Palmer Sta. 757)", Cuba (Palmer, 1934, p. 239). In addition Mrs. Palmer sent several microspheric specimens from a second location, identified by her. One of these specimens was made into a transverse section and is illustrated as figure 10, Plate 3.

The description and illustrations of *O. bermudezi* are based on the microspheric form. The megalospheric form is briefly mentioned but not adequately described, and no illustrations of it have been given. Therefore, topotype specimens were selected from the type sample for sectioning to compare this species with certain specimens from Georgia (see Bull. Amer. Paleont., vol. 35, No. 148.)

Measurements made from the megalospheric form of these specimens follow:

Median section of topotypes of *Operculinoides bermudezi*

Height (mm.)	1.8	2.63	2.25	2.48
Width (mm.)	1.71	2.3	2.1	2.05
Diameters of initial chamber (μ)	160x190	100x130	160x215	140x210
Diameters of second chamber (μ)	100x180	100x110	130x180	120x190
Distance across both chambers (μ)	270	220	310	290
Number of whorls (no.)	2½	2½	2¾	2½
Chambers in first volution (no.)	9	9	9	9
Chambers in final volution (no.)	17	22	26	24

Transverse sections of topotypes of *Operculinoides bermudezi*

Height (mm.)	1.8	1.7	1.85	2.3	2.4	2.12	2.38
Thickness (mm.)	0.83	0.7	0.75	0.92	0.75	1.08	0.7
Distance cross both embryonic chambers (μ)	180	170	280	360	170	320	200
Diameter of axial plug (μ)	400	400	470	600	500	650	500

Measurements made from the microspheric form of these specimens follow:

Median section of topotypes of *Operculinoides bermudezi*

Height (mm.)	3.15
Width (mm.)	2.8
Number of whorls (no.)	5
Chambers in final volution (no.)	23
Height of final chambers (μ)	450

Transverse sections of topotypes of *Operculinoides bermudezi*

Height (mm.)	3.62	4.18
Thickness (mm.)	1.23	1.6
Diamter of axial plug (μ)	700	650

Remarks.—It became apparent as these specimens were studied and compared with similar species recorded in the literature that most of the species described by various authors under several specific names should be combined. In part, the confusion about *O. bermudezi* has arisen because the megalospheric form was not described or illustrated. Also, *O. bermudezi* was assigned by Mrs. Palmer to the Upper Cretaceous although later she revised her opinion. In a personal letter to Miss Caudri (1948, p. 475) Mrs. Palmer stated that she believed the type locality of *O. bermudezi* to be Eocene contaminated with reworked Cretaceous Foraminifera. Davies (1949), p. 114) also stated "the late Mrs. Palmer told me (letters of 10th March and 13th August, 1946) that *R. bermudezi* is not a Cretaceous form, as thought when she originally described it, but is a Paleocene one."

In addition to the species listed in the synonymy of *O. bermudezi,* many of the new species proposed by Mrs. de Cizancourt (1948 b) from the Paleocene of Barbados appear to be *O. bermudezi.* However, specimens from Nicaragua assigned by Mrs. de Cizancourt (1948a, pl. 23, figs 4, 7, 12) to *Miscellanea antillea* are certainly *Pellatispirella matleyi* (Vaughan).

Finally, it may be stated that *Operculinoides catenula* (Cushman and Jarvis) (1932, p. 42) is similar to *O. bermudezi.* The original illustration of *O. catenula* is a drawing. Therefore, the writer had the type photographed for comparison with *O. bermudezi* (Pl. 3, fig. 1). As the type is the only one available, thin sections could not be made. Unless more specimens are collected and thin sections made, it is impossible to do more than indicate the similarity between the two species.

Operculinoides bermudezi can be distinguished from the other common Paleocene species, *O. georgianus* Cole and Herrick, *nom. nov.* (Bull. Amer. Paleont., vol. 35, No. 148) (=*Miscellanea soldadensis* Vaughan and Cole, 1941, p. 36, not *Operculinoides soldadensis* Vaughan and Cole, 1941, p. 40) by its more lenticular test both in the megalospheric and microspheric generations and the thicker wall of its spiral lamina.

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PLATES

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Figures 1, 4, 9, 10, x 40; 2, x 230; 3, 5, 8, 11, x 20; 12, 13, x 12.5

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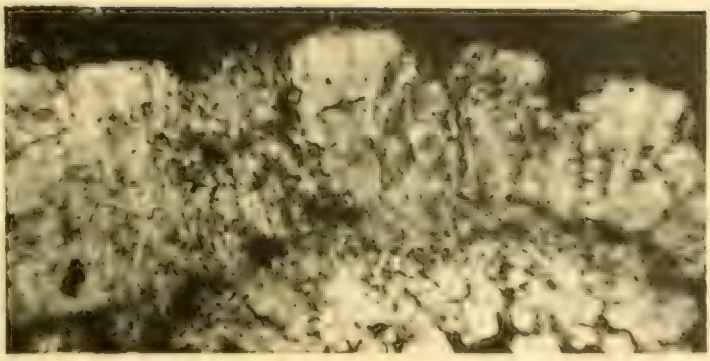

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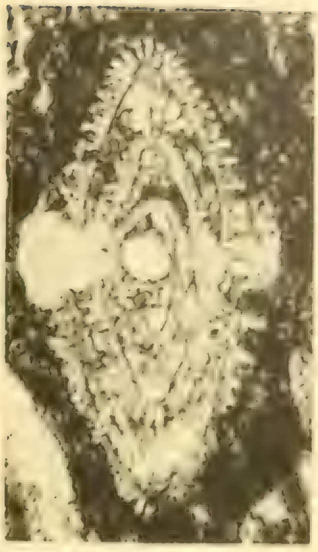

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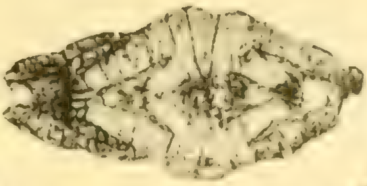

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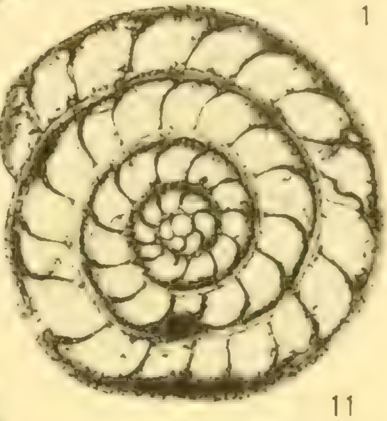

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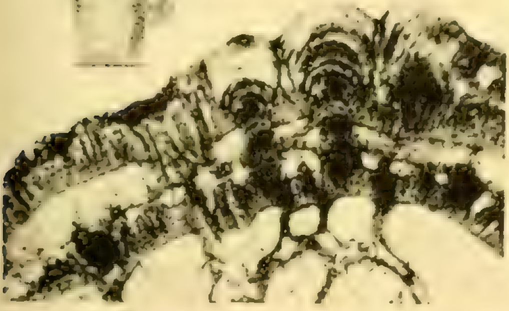

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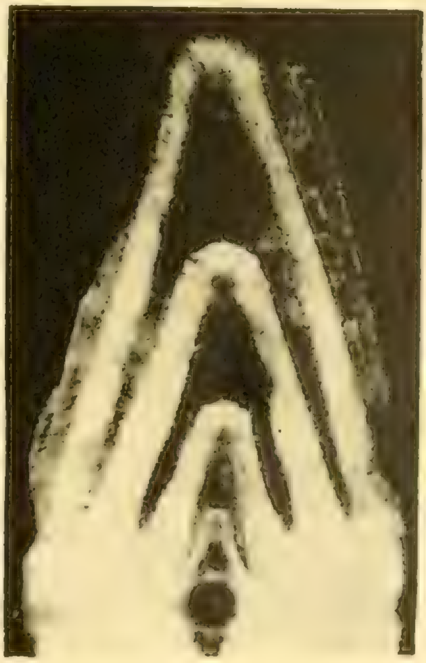

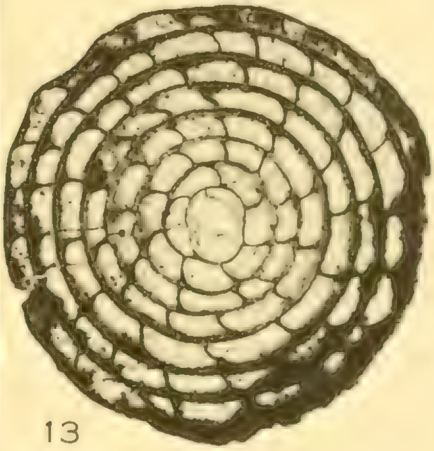

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Fig. 1, of a specimen from the Chipola River, below the wagon bridge, east of Marianna, Florida; 2, of a specimen from 4.5 miles west of Williston, Levy County, Florida; 3, of a specimen from the No. 1 Chehaw Park well, Georgia at a depth of 580-590 feet; 4, of a specimen from the cut on the Carretera Central under the railroad bridge at Central San Antonio, 2 kilometers west of Madruga, Havana Province, Cuba (Palmer sta. 757); 5, same locality as 1; 6, of a specimen from southern Miahuapam, Vera Cruz, Mexico, collection of E. Gevaerts, No. 269, donated by R. Wright Barker; 7, of a specimen from Muara Djaing on the Tabalong River, southeastern Borneo, donated by the late T. Wayland Vaughan; 8 of a specimen from the core hole SL-84, Gatun Lake area, 3.6 miles north-northwest of Frijoles on the divide between Quebrada Juan Gallegos and Quebrada La Chinilla, Panama Canal Zone; 9, Chaumont, Paris Basin France, donated by the late T. Wayland Vaughan; 10, of a specimen from Bracklesham, Sussex, England, donated by the late G. D. Harris.

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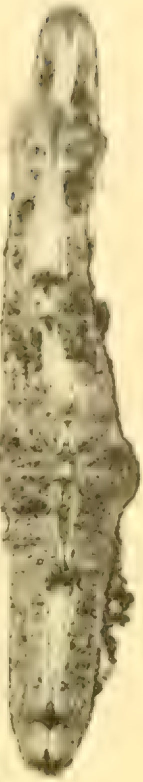
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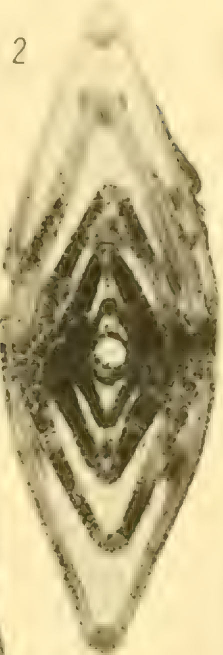
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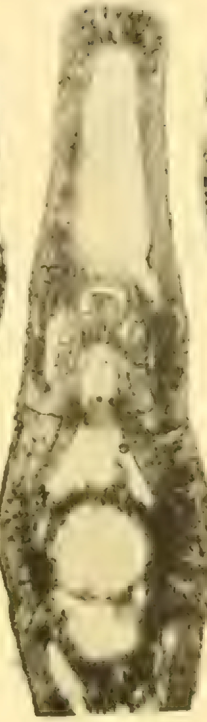
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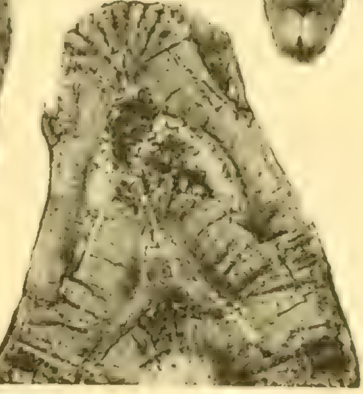
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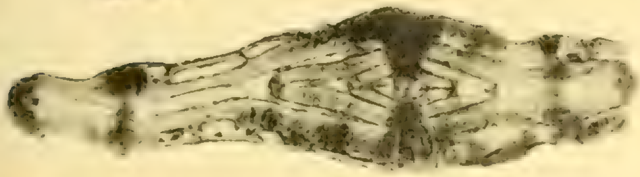
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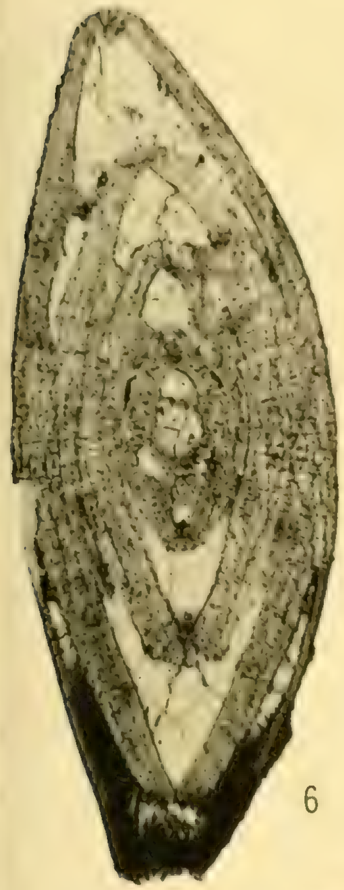
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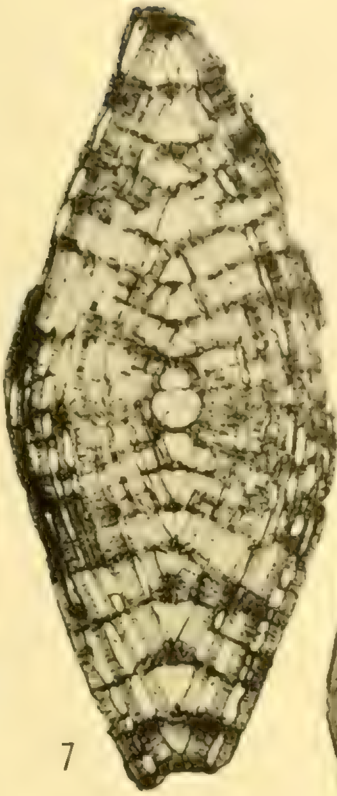
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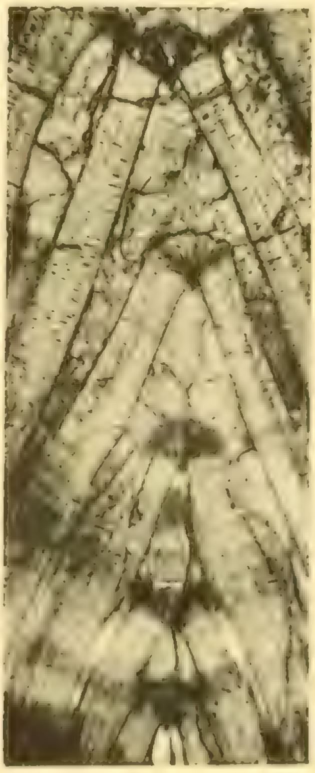
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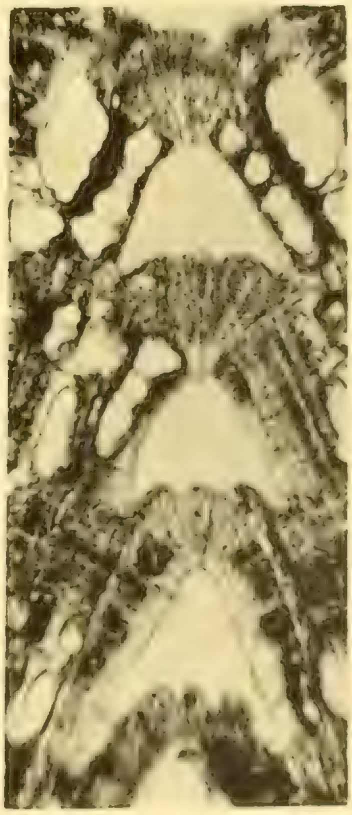
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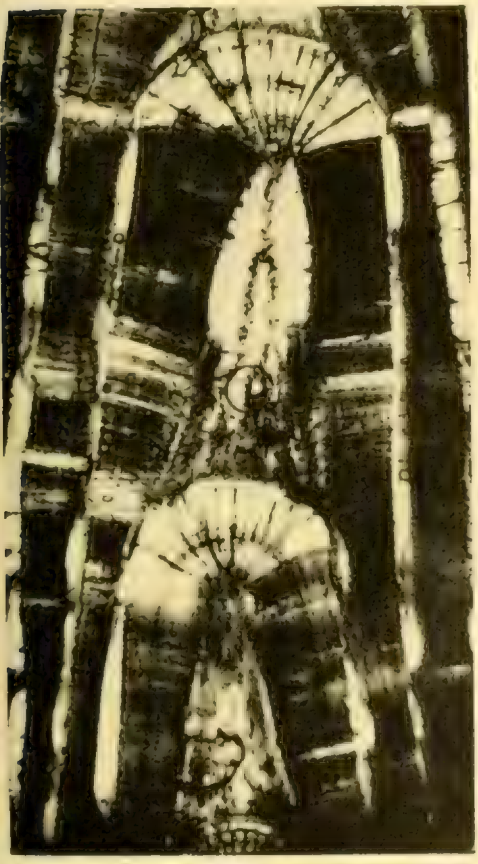
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Figure 1, of a specimen from a pit at Lizard Springs near Guayaguayare, southeastern Trinidad, British West Indies; 2-9, 11, 12, of specimens from the cut on the Carretera Central under the railroad bridge at Central San Antonio, 2 kilometers west of Madruga, Havana Province, Cuba (Palmer sta. 757); 10, of a specimen 1 kilometer southwest of Madruga (Palmer sta. 832).

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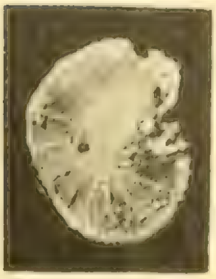
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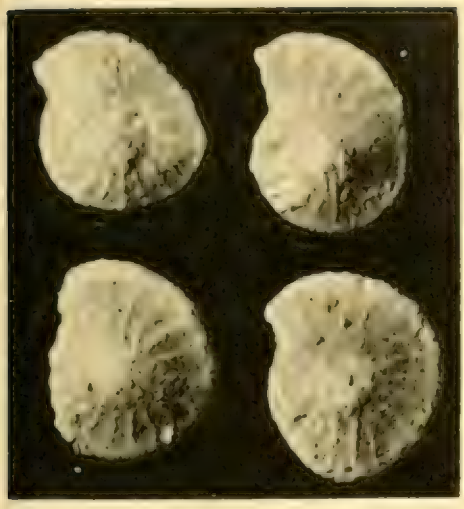
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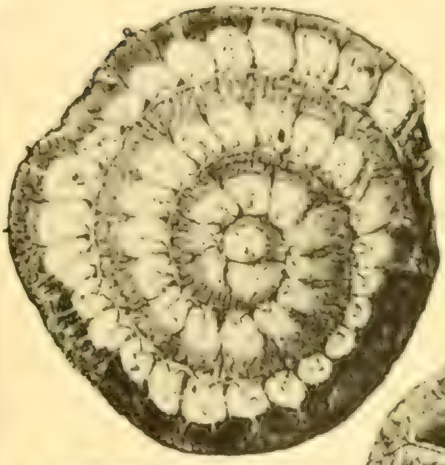
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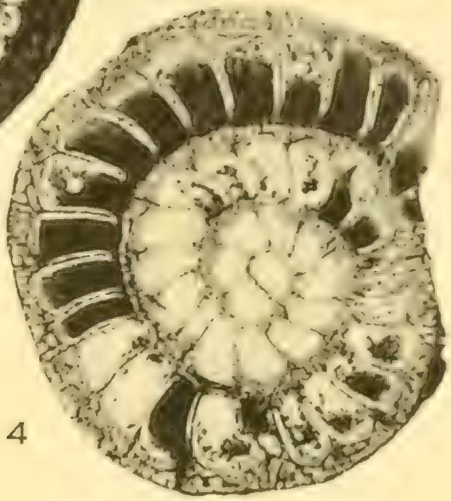
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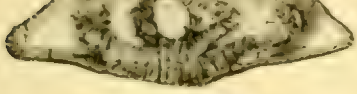
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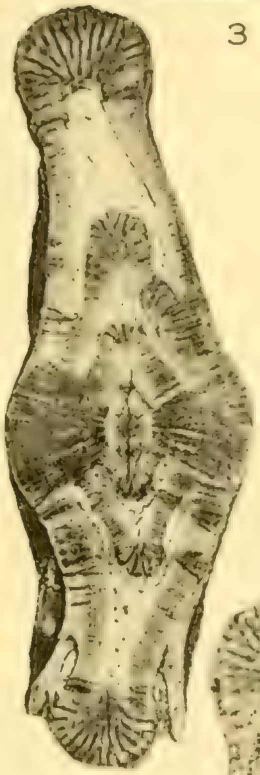
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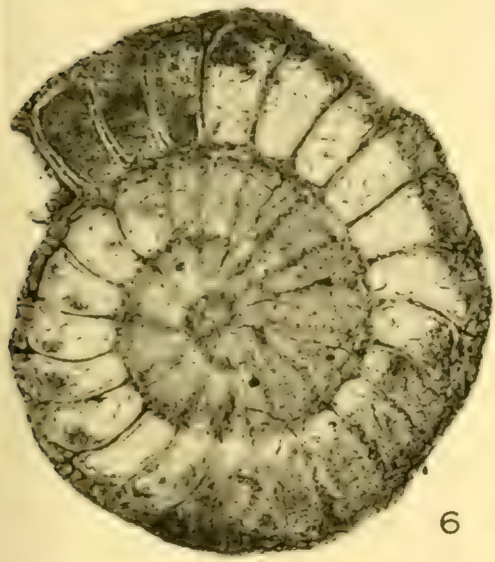
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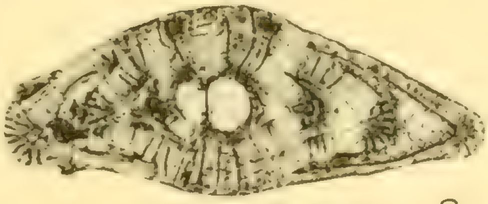
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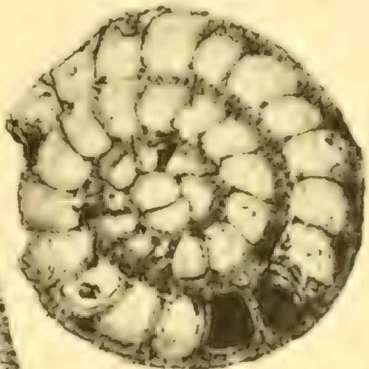
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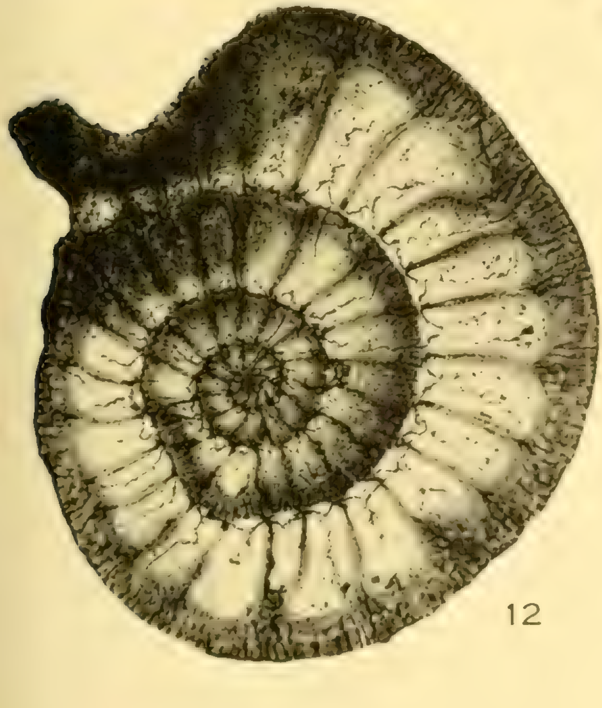
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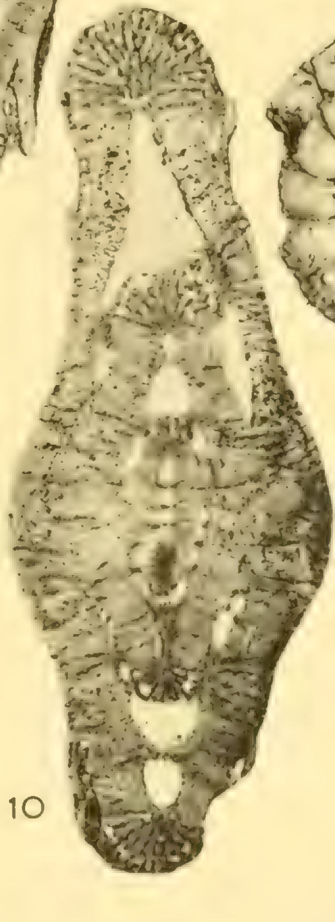
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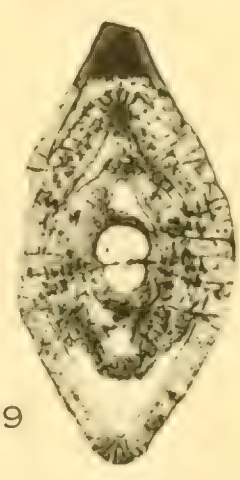
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TWO SPECIES OF LARGER FORAMINIFERA FROM PALEOCENE BEDS IN GEORGIA

By

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December 24, 1953

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W. Storrs Cole
Cornell University, Ithaca, N. Y.

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Stephen M. Herrick
U. S. Geological Survey, Atlanta, Ga.

ABSTRACT

Two species of larger Foraminifera, *Operculinoides georgianus* Cole and Herrick and *Pseudophragmina* (*Athecocyclina*) *stephensoni* (Vaughan), from wells in Georgia are illustrated and described. The beds in which these species occur are correlated with the Porters Creek clay of the Midway group (Paleocene). As the species *Miscellanea soldadensis* Vaughan and Cole is transferred from the genus *Miscellanea* to *Operculinoides* a new specific name, *Operculinoides georgianus* Cole and Herrick, is proposed for *Miscellanea soldadensis* Vaughan and Cole (1941).

INTRODUCTION

In investigations of ground-water in Georgia in cooperation with the Georgia Department of Mines, Mineralogy and Geology two species of larger Foraminifera were discovered by Herrick in certain wells drilled to beds in Dougherty, Early, Lee, Calhoun, and Seminole counties that appear to correlate with the Porters creek clay of the Midway group. These specimens are of sufficient interest to be illustrated and described because one of the species, *Operculinoides georgianus* Cole and Herrick, nom. nov. (=*Miscellanea soldadensis* Vaughan and Cole), has a wide geographic distribution in the Caribbean region (Trinidad, see Vaughan and Cole, 1941, p. 36; Barbados, see Vaughan, 1945, p. 30) and Venezuela (Caudri, 1944, p. 23); and the other, *Pseudophragmina* (*Athecocyclina*) *stephensoni* (Vaughan), is known only from Mexico (Vaughan, 1929, p. 16). The occurrence of these two species together in

[1] Publication authorized by the Director, U. S. Geological Survey

Georgia not only substantiates the Midway age of *P.* (*A.*) *stephensoni* but also allows a correlation to be made between Georgia and other localities in the Caribbean area where these species occur.

LOCATION OF WELLS

The location of the wells and the approximate depths of the larger foraminiferal beds follow:

County	Name of well	Location	Approx. limits of larger foraminiferal zone (feet)
Calhoun	City of Leary	East side of city, north of municipal water tank.	360 (One sample only)
	No. 1 City of Morgan	Near city water tower, which is north of courthouse.	360-430
Dougherty	No. 1 Reynolds Lumber Co.	Half a mile north of Locketts.	520-610
	No. 10 City of Albany	South side of Roosevelt Avenue, in second block west of Jefferson Street.	560-660
	No. 11 City of Albany	Corner of Cleveland and Pine streets.	568-660
	No. 13 City of Albany	Three-fourths block east of Jefferson Street, half a block south of Central of Georgia Railroad at waterworks plant.	583-675
Early	No. 1 A. C. Chandler	About six miles northwest of Saffold, Georgia.	615-970[2]
Lee	No. 1 Chehaw Park	Half a mile west of main park entrance.	510-620
Seminole	No. 1 Emily Harlow	A third of a mile northeast of the center of Iron City on Dry Creek.	1010-1020[2]

[2] The No. 1 Emily Harlow well and the No. 1 A. C. Chandler well are the only wells that have *P.* (*A.*) *stephensoni*. In the No. 1 Emily Harlow well *P.* (*A.*) *stephensoni* occurs at a depth of 1010 to 1020 feet. Other specimens of this species submitted from this well are apparently cavings. However, *O. georgianus* occurs in the same sample. Therefore, these two species occur together.

LITHOLOGY OF THE LARGER FORAMINIFERAL ZONE

Up-dip.—The upper portion of the zone of larger Foraminifera is composed of fine-grained, very glauconitic, calcareous, somewhat indurated fossiliferous sand with a few thin stringers of white, glauconitic arenaceous, fossiliferous limestone. Below this is dark-gray, lignitic, fissile, tough, fossiliferous clay. In some wells the clay appears to interfinger with thin stringers of sand.

Down-dip.—The first appearance of the larger foraminiferal zone is marked by an arenaceous, glauconitic, fossiliferous limestone. Below this limestone occur fine-grained, glauconitic sand interbedded with tough, gray, lignitic, fissile, fossiliferous clay.

ASSOCIATED SMALLER FORAMINIFERA

Smaller Foraminifera are found with varying frequencies in association with the larger Foraminifera. A composite list of the most diagnostic species, identified by Herrick, follows:

Anomalina midwayensis (Plummer)
Boldia madrugaensis Cushman and Bermudez
Bulimina cacumenata Cushman and Parker
Cibicides newmanae (Plummer)
Discorbis midwayensis Cushman
Discorbis midwayensis soldadoensis Cushman and Renz
Eponides elevatus (Plummer)
Globorotalia crassata aequa Cushman and Renz
Gümbelina midwayensis Cushman
Gyroidina subangulata (Plummer)
Nodosaria latejugata Gümbel
Polymorphina cushmani Plummer
Robulus degolyeri (Plummer)
Robulus wilcoxensis Cushman and Ponton
Sigmomorphina soldadoensis Cushman and Renz
Siphonina prima Plummer
Valvulineria wilcoxensis Cushman and Ponton

DESCRIPTION OF SPECIES

Family **Camerinidae**

Genus **Operculinoides** Hanzawa, 1935[3]

Operculinoides georgianus Cole and Herrick, nom. nov. Pl. 1, figs. 1-21; Pl. 2, figs. 1-3.

1941. *Miscellanea soldadensis* Vaughan and Cole, Geol. Soc. Amer., Sp. Paper 30, p. 36, pl. 4, figs. 8, 9. Not *Operculinoides soldadensis* Vaughan and Cole, 1941, *idem,* p. 40, 41, pl. 9, figs. 5-8; pl. 10, figs. 1, 2.
1944. *Ranikothalia soldadensis* (Vaughan and Cole), Caudri, Bull. Amer. Paleont., vol. 28, No. 114, pp. 23, 24, pl. 4, fig. 19; pl. 5, figs. 24, 26.
1945. *Miscellanea soldadensis* Vaughan and Cole, Vaughan, Geol. Soc. Amer., Mem. 9, pp. 30, 31, pl. 5, figs. 2-5.

Megalospheric form.—Test small, compressed lenticular with a bluntly rounded, slightly thickened periphery. A distinct, elevated boss, 0.3 mm. in diameter, from which radiate straight, slightly raised sutures, occurs in a subcentral position.

Measurements of median thin sections follow:

Median sections of *Operculinoides georgianus*

	Chehaw Park well		City of Leary well		No. 10 City of Albany well
Locality	570-580′	580-590′	360′		617-630′
Height (mm.)	2.0	1.88	1.19	1.55	2.56
Width (mm.)	1.9	1.65	1.0	1.38	1.96
Diameters of initial chamber (μ)	110x120	130x160	130x150	150x160	200x290
Diameters of second chamber (μ)	70x110	80x120	100x140	60x155	150x250
Distance across both chambers (μ)	200	220	250	210	370
Number of whorls (no.)	2½	2¼	1½	2⅛	2
Chambers in first volution (no.)	7	8	9	9	10
Chambers in final volution (no.)	21	16	13	16	21

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[3] An analysis of this genus is given in the previous Bull. Amer. Paleont., vol. 35, No. 147.

The chamber walls are either straight or slightly recurved. The proximal ends of the chamber walls are slightly expanded and in accurately centered thin sections do not touch the revolving wall. Each chamber wall encloses a canal about 10 μ in diameter. At the distal end this canal divides into a series of minor canals that radiate outward through the marginal cord.

Each chamber cavity viewed in median section is bounded by the marginal cord of the revolving wall at the proximal side, by the side of the chamber wall along the radial portions, and by a continuation of these side walls along the distal edge. As these walls are denser in construction, the revolving wall is composed of two zones, an inner compact layer and an outer, porous one, except at the places where the radial canal joins the marginal cord. At these places the marginal cord is in contact with the central, radial canal of the chamber wall.

Measurements of transverse sections follow:

Transverse sections of *Operculinoides georgianus*

	Chehaw Park well				City of Leary well		No. 10 City of Albany well	
Locality	570-580′		580-590′		360′		617-630′	
Height (mm.)	1.8	1.58	1.3	1.6	1.15	1.7	1.58	2.38
Thickness (mm.)	0.57	0.52	0.57	0.46	0.46	0.58	0.75	0.61
Distance across embryonic chambers (μ)	150	170	230	180	250	150	180	300
Diameter of axial plug (μ)	400	360	340-400	400	-	390	300-600	350

The marginal cord viewed in transverse sections is well developed, distinct, composed of radial canals about 5 μ in diameter between wedge-shaped areas that have a surface diameter of 20 to 40 μ. Many specimens have a series of rounded pores, about 10 μ in diameter, developed on the base of the marginal cord.

On each side of the test over the embryonic chambers there is a series of radiating canals that separate the axial plug into wedge-shaped pieces. These canals are better developed in some specimens than in others. The side walls of the test between the marginal cord and the axial plug appear to be perforated by fine transverse canals.

The aperture is a distinct, semicircular slit, 15 to 20 μ high, over the marginal cord and at the base of the chamber.

Microspheric form. — Test compressed lenticular, commonly with the two sides of the test nearly parallel. Periphery wide, bluntly round, thickened. There is a slightly raised, subcentral boss about 0.4 mm. in diameter from which radiate nearly straight, slightly elevated sutures.

A specimen with a height of 3.0 mm. and a width of 2.65 mm. has 4½ whorls with 25 chambers in the final volution. The height of the final chambers is about 400 μ.

Measurements of transverse sections follow:

Transverse sections of *Operculinoides georgianus*

Locality	No. 10 City of Albany well at 630'-645'			
Height (mm.)	3.0	2.89	3.65	2.8
Thickness (mm.)	0.55	0.54	0.52	0.55
Diameter of axial plug (μ)	250	310	300	200

Discussion. — This species differs from *O. bermudezi* (D. K. Palmer), both in the megalospheric and in the microspheric generations, in having a more compressed test and less robust walls.

Family **Discocyclinidae**

Genus **Pseudophragmina** H. Douvillé, 1923

Subgenus **Athecocyclina** Vaughan and Cole, 1940

Pseudophragmina (Athecocyclina) stephensoni Vaughan. Pl. 2, figs. 4-11

1929. *Discocyclina stephensoni* Vaughan, U. S. Nat. Mus., Proc., vol 76, Art. 3, p. 16, pl. 6, figs. 1-4.

1945. *Pseudophragmina* (*Athecocyclina*) *stephensoni* (Vaughan), Vaughan Geol. Soc. Amer., Mem. 9, p. 101, pl. 45, figs 3, 4.

Test small, flat, thin, fragile without a marked umbo. Small, slightly elevated papillae are distributed evenly over the surface.

Measurements of three equatorial sections follow:

Equatorial sections of *P.* (*Athecocyclina*) *stephensoni*

Locality	No. 1 Emily Harlow well at 1020-1030'	1030-1040'	
Diameter (mm.)	1.4	2.2	2.85
Diameter of initial chamber (μ)	75	75	100
Diameter of second chamber (μ)	60x170	80x160	90x240
Distance across both chambers (μ)	145	160	190
Thickness of outer wall (μ)	8	10	10
Width of average annulus (μ)	15	50	60
Thickness of annular walls (μ)	15	10	10

The initial chamber is nearly spherical, with the larger, reniform second chamber partially embracing it. In one specimen the first ring of periembryonic chambers completely envelopes the embryonic chambers. In another there is a small space about 100 μ wide on the periphery of the initial chamber where this ring does not close. The periembryonic ring of the third specimen does not show clearly.

The annular walls are well preserved. They are wavy and in places join those of the next adjacent ring. There are in places thickenings of the annual rings, which may represent the stubs of radial chamber walls.

Measurements of three vertical sections of specimens follow:

Vertical sections of *P.* (*Athecocyclina*) *stephensoni*

Locality No. 1 Emily Harlow well at	1050-1060′	1220-1230′	
Diameter (mm.)	2.85+	2.9+	4.2
Thickness (mm.)	0.59	0.48	0.49
Embryonic chambers:			
Length (μ)	160	190	240
Height (μ)	100	110	90
Equatorial layer:			
Height at center (μ)	15	10	10
Height at periphery (μ)	30	20	20
Thickness of floors and roofs (μ)	20	20	20
Lateral chambers:			
Number	9	5	6
Length (μ)	40-100	50-90	70-90
Height (μ)	10	10	5
Thickness of floors and roofs (μ)	20	20	20
Diameter of pillars (μ)	40	40-50	30

The cavities of the lateral chambers are low, but distinct. They are not in regular tiers, but overlap. The floors and roofs are thick.

Small pillars are irregularly distributed throughout the length of the vertical sections.

Discussion—Five species and one variety of *Athecocyclina* have been described from the Caribbean area. These species, the dates when they were described, the geologic age assigned to them, and their type localities follow:

Middle Eocene

P. (*A.*) *jukes-brownei* Vaughan, 1945, Barbados

Lower Eocene

cookei (Vaughan), 1936, Alabama

Paleocene

stephensoni (Vaughan), 1929, San Luís Potosí, Mexico
soldadensis Vaughan and Cole, 1941, Soldado Rock, Trinidad
soldadensis var. *calebardensis* Vaughan, 1945, Barbados
macglameriae Vaughan, 1945, Alabama

In addition Miss Caudri (1944, p. 14) compared certain Venezuela specimens from the Paleocene with *P.* (*A.*) *cookei.* These specimens are *P.* (*A.*) *stephensoni.* Mrs. de Cizancourt (1951, p. 62) recorded without discussion or illustration four species of *Athecocylina, P.* (*A.*) *cookei, P.* (*A.*) *macglameriae, P.* (*A.*) *soldadensis,* and *P.* (*A.*) *stephensoni* from the Paleocene and lower Eocene of Venezuela.

Although the features of the embryonic and periembryonic chambers may have some value in distinguishing the species, the major specific characters appear in the vertical sections. Unfortunately, the illustrations of the vertical sections of some of these species are unsatisfactory.

As the specimens from Georgia seemed to have the features in vertical section ascribed to *P.* (*A.*) *stephensoni,* the senior author restudied the type sections. Lloyd G. Henbest, of the U. S. Geologcal Survey, kindly rephotographed the best vertical section and that photograph is reproduced as figure 8, Plate 2. From the structures observed in this and other vertical sections of the types, the specimens from Georgia are assigned to this species.

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PLATES

PLATE I (4)

Explanation of Plate 1 (4)

Figure		Page
1-21.	**Operculinoides georgianus** Cole and Herrick, nom. nov.	6

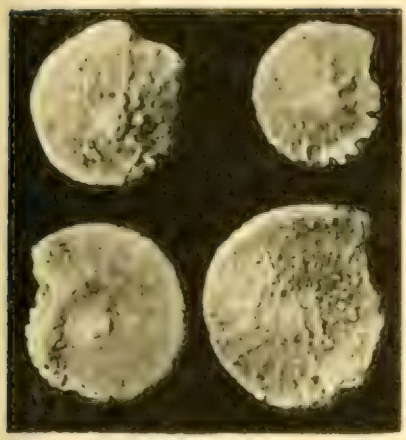
1. External views of 4 megalospheric specimens. 2-6. Median sections of a megalospheric specimen. 7. Median section of a microspheric specimen. 8, 9. Transverse sections of microspheric specimens. 10-21. Transverse sections of megalospheric specimens.

Figure 17 is an enlargement of 18; figure 21 is an enlargement of 15.

Figs. 1, 2, 5, 10, 11, of specimens from the City of Leary well at a depth of 360 feet; 3, 4, 14, 17-20, of specimens from the No. 1 Chehaw Park well; 3, 17-19, at a depth of 580-590 feet; 4, 14, 20 at a depth of 570-580 feet; 6, 7, 12, 13, 15, 16, 21, of specimens from the No. 10 City of Albany well at a depth of 617-630 feet; 8, 9, of specimens from the No. 11 City of Albany well at a depth of 630-645 feet.

Figs. 1, x 10; 2-16, 18-20, x 20; 17, 21, x 40.

The expense of the plates has been defrayed by the William F. E. Gurley Foundation for Paleontology of Cornell University.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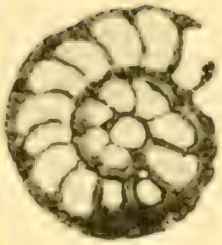
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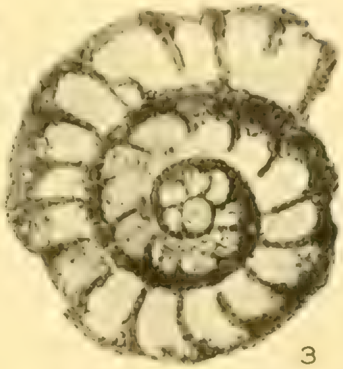
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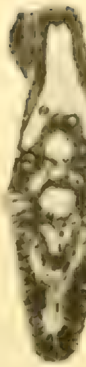
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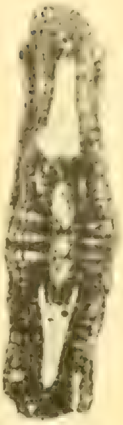
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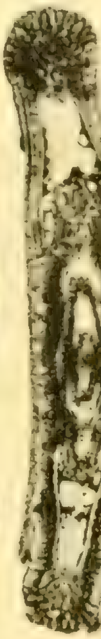
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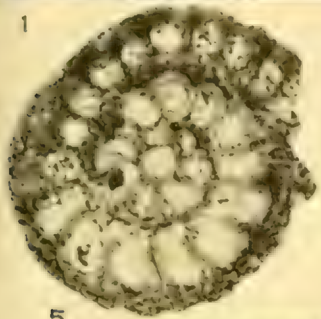
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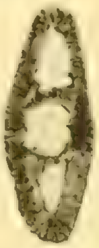
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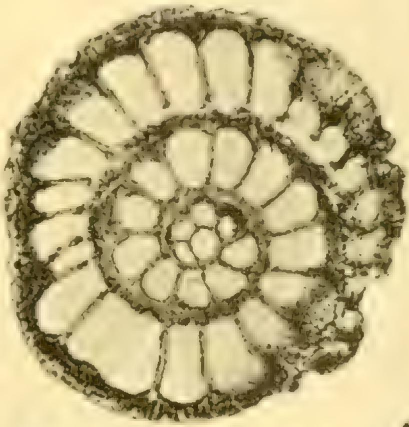
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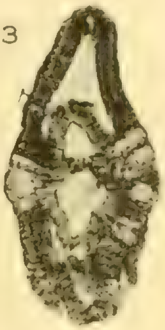
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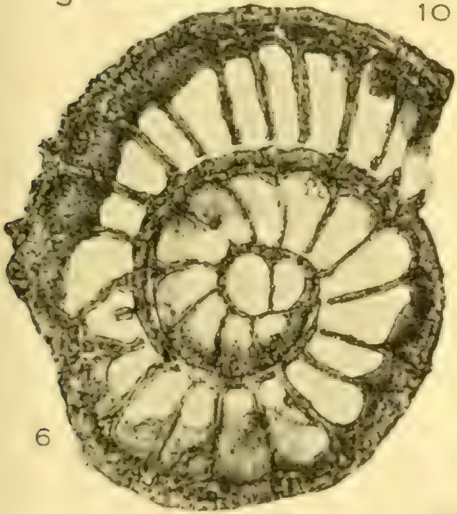
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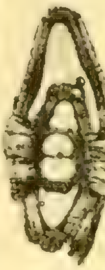
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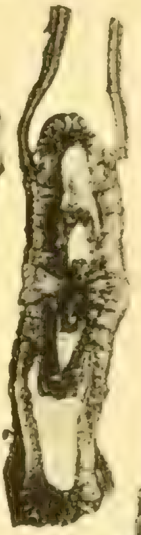
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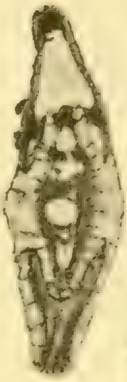
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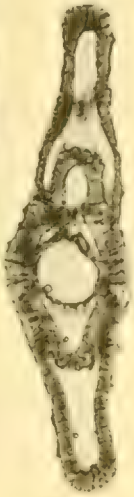
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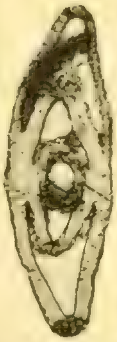
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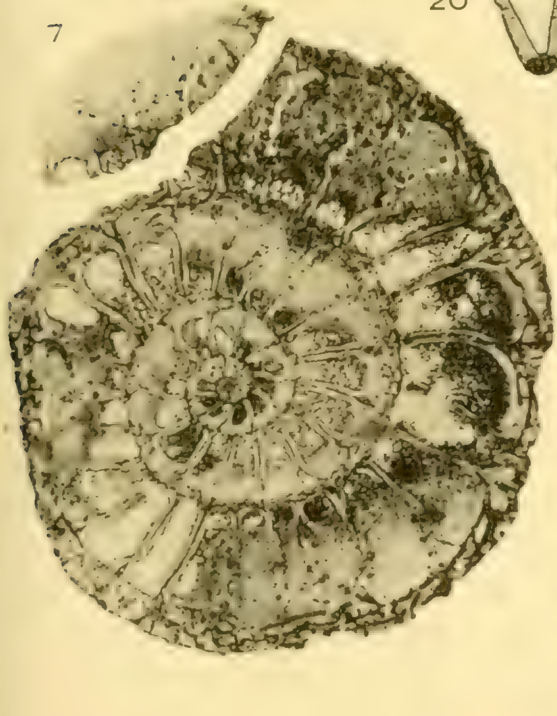
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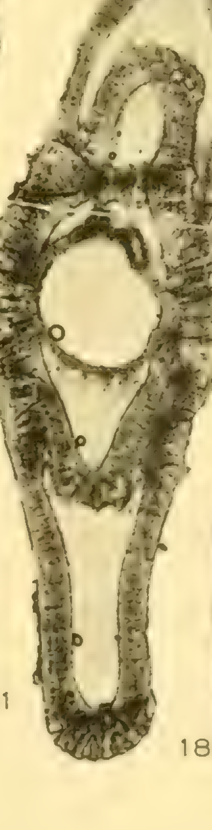
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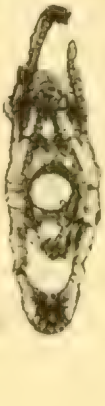
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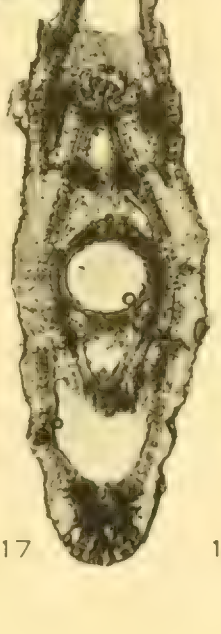
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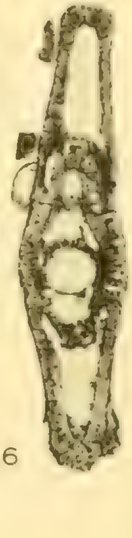
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PLATE 2 (5)

Explanation of Plate 2 (5)

Figure		Page
1- 3.	**Operculinoides georgianus** Cole and Herrick, nom. nov.	6

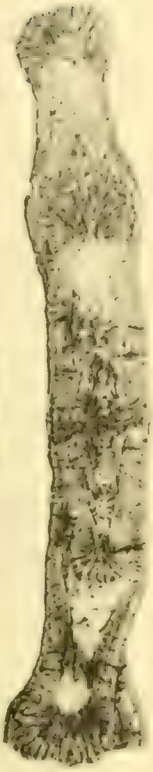
Transverse sections of microspheric individuals; 2 is an enlargement of the top part of 1 to show the structure of the marginal cord and the wall of the spiral lamina.

Figure		Page
4-11.	**Pseudophragmina (Athecocyclina) stephensoni** (Vaughan)	8

4-8. Vertical sections; 7 is an enlargement of the central portion of 6; 8 is a new illustration of one of the syntypes (see Vaughan, 1929, pl. 6, fig. 2). 9-11. Equatorial sections; 11 is an enlargement of the central part of 10.

Figs. 1-3, of specimens at a depth of 617-630 feet in the No. 11 City of Albany well; 4-7, 9-11, of specimens from the No. 1 Emily Harlow well; 4, at a depth of 1050-1060 feet; 5-7, a depth of 1020-1030 feet; 9, at a depth of 1030-1040 feet; 10, 11, at a depth of 1230-1240 feet; 8, of a specimen from loose boulders, No. 194, canyon, about 2 miles west of San Pedro, and No. 196, Guerrero road, about 3 kilometers east of Tanlajas, State of San Louis Potosi, Mexico, collected by L. W. Stephenson.

Figs. 1, 3, 4, 6, 10, x 20; 2, 5, 7, 8, 9, 11, x 40.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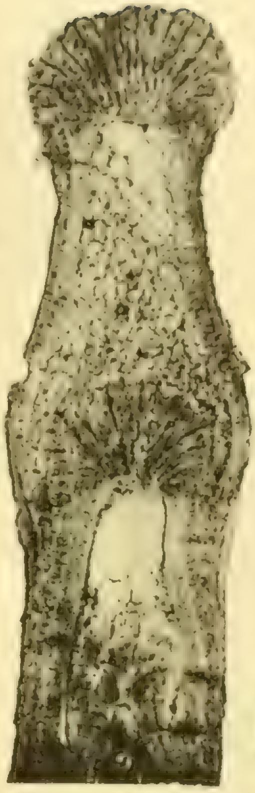
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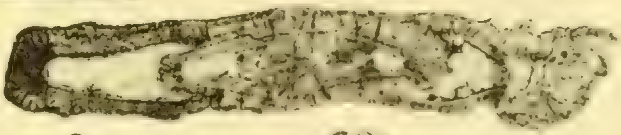
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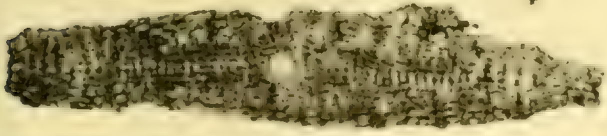
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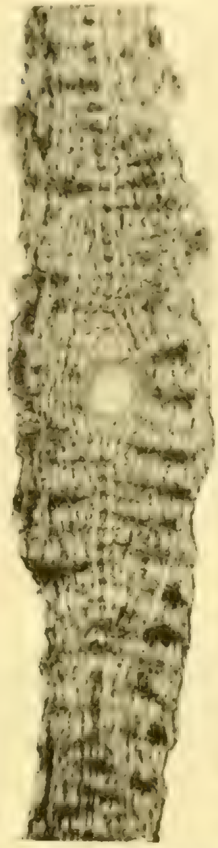
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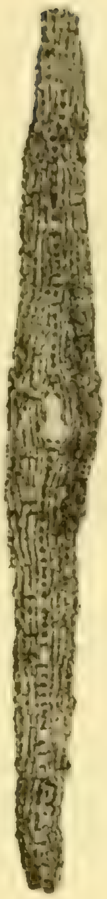
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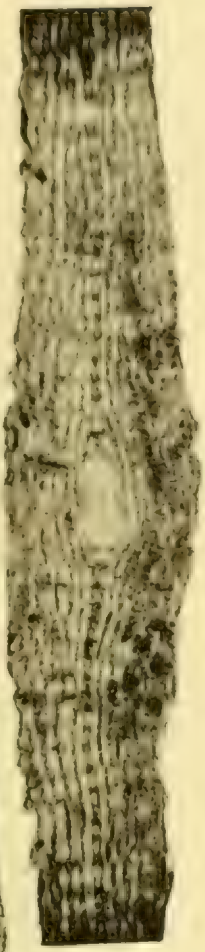
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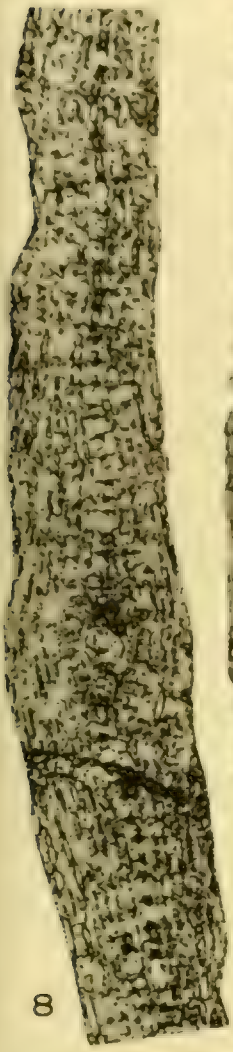
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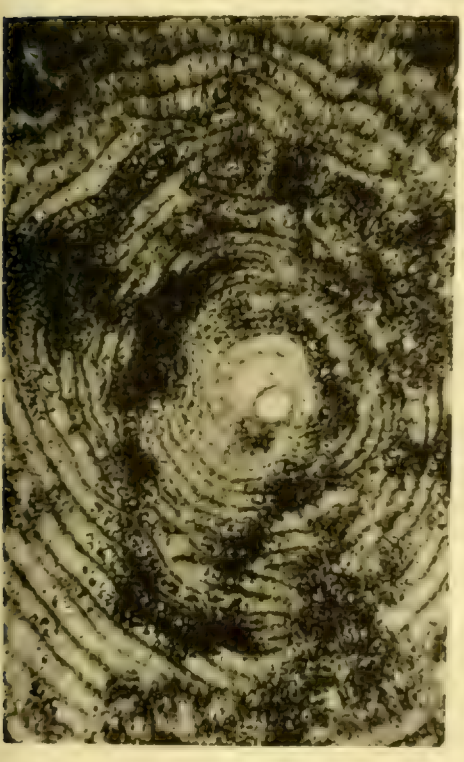
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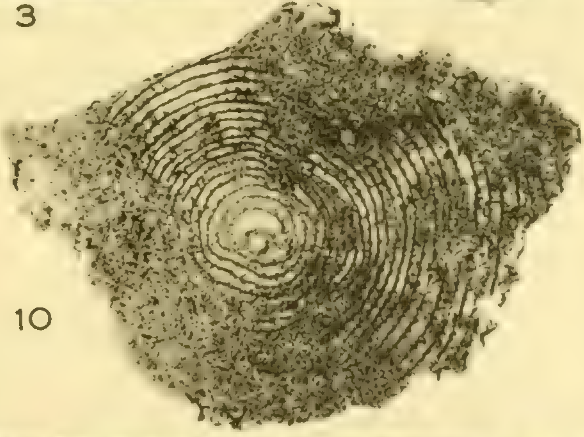
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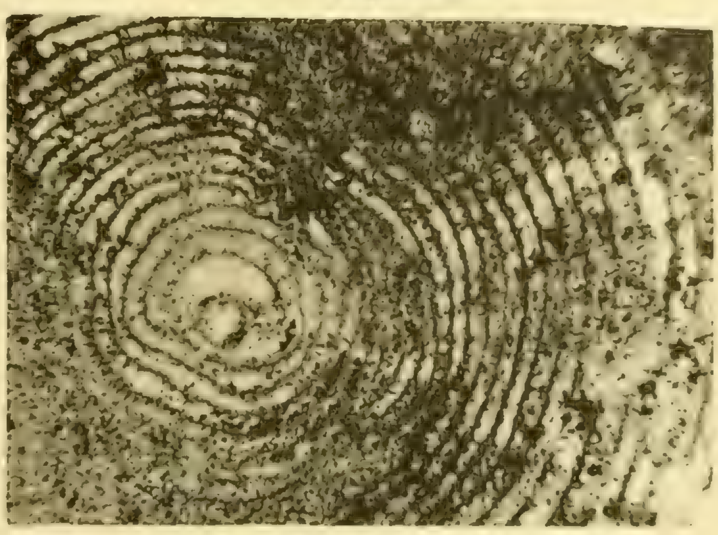
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Vol. 35

No. 149

CONTRIBUTIONS TO KNOWLEDGE OF THE BRAZILIAN PALEOZOIC: NO. 1

A. INTRODUCTORY SURVEY OF THE BRAZILIAN CARBONIFEROUS

By

Kenneth E. Caster

B. NOTES ON SOME BRACHIOPODS FROM THE ITAITUBA FORMATION (PENNSYLVANIAN) OF THE TAPAJOS RIVER, BRAZIL

By

Hugh Dresser

March 31, 1954

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CONTRIBUTIONS TO KNOWLEDGE OF THE BRAZILIAN PALEOZOIC—NO. 1

Kenneth E. Caster and Hugh Dresser

A. INTRODUCTORY SURVEY OF THE BRAZILIAN CARBONIFEROUS

Kenneth E. Caster
University of Cincinnati

Mr. Dresser's study is the first of a projected series of paleontologic works on the Brazilian Paleozoics. The materials employed in this and the succeeding works derived from my personal collections made during a three year stay in Brazil (1945-1948) plus materials furnished through the courtesy of the various geological agencies of the Brazilian Government (Divisão de Geologia e Mineralogia, Conselho Nacional de Petróleo, and the Geology and Paleontology Department of the University of São Paulo). All of these agencies cooperated generously in making field studies and fossil collections possible in most of the Paleozoic areas of Brazil.

One or more further investigations of the Amazonian Carboniferous fauna is planned for the series; likewise a monographic reëvaluation of the Amazonian Devonian faunas. Collections are at hand for description of a new Devonian fauna from the southern border of the Maranhão-Piauí Basin, and likewise for a broad revision of the Devonian fauna of the Paraná Basin.

This paper is based on the first silicified material to be artifically etched from the Carboniferous limestones of Brazil. Since the initial discovery of the Amazonian Carboniferous (Coutinho, 1863, Agassiz, 1869, Hartt, 1870) the extraordinarily fine, naturally etched nature of the material has been known. Specimens of exceptional delicacy and perfection have been recovered from residual soils and even from river sands ever since the discovery. However, it was felt that acid bath techniques might furnish further morphologic details, especially of the more fragile forms and also of earlier stages of growth. All depended on the nature of the silicification, and especially on the depth of penetration of the seemingly surficial phenomenon. A considerable store of promising limestone and shales was collected in the summer of 1948 during a survey trip into the Amazonian Paleozoic area under the sponsorship of the Brazilian Petroleum Council. Through the perseverence and ingenuity of Mr. Dresser the muddy bituminous limestone was made to yield a substantial body of excellent silicified shell material. However, due to the great amount of time and labor spent in perfecting techniques and in tending the acid baths and garnering the fragile shells, Mr. Dresser could, in the time available, undertake the paleontologic study of only a small part of the fauna. The new facts on brachiopod morphology and new genera and species which his study has brought to light, coupled with his extra-Brazilian comparisons, make a worthwhile addition to knowledge of a subject inadequately known. Although a single comprehensive restudy of the fauna is needed, rather than further piecemeal analyses, there seems to be no immediate prospect for such a work.

The rich and beautiful fauna of these beds has been receiving only sporadic and piecemeal attention since it was first described by Derby (1874). Unfortunately that splendid publication is so rare and the illustrations so faded[1] that it is difficult to gain an adequate literature impression of the fauna now. Happily, not only the original specimens, mounted on boards as photographed in 1873 are still intact at Cornell University, but also the original glass negatives from which the published plates were printed. Through the kindness of Dr. W. Storrs Cole, of Cornell University, Mr. Dresser and I were furnished with excellent photographic prints from these negatives.[2]

---

[1] It is interesting, in view of the unfortunate outcome, to read Hartt's belief (*in* Derby, 1874, p. 63, footnote) that the new process of photographic plate reproduction, perfected in the photographic laboratory at Cornell, and printed on "plain paper," would prove permanent. Despite the fiasco of the method of reproduction, we could profit greatly from the process of photography employed in that laboratory if it were only known. Instead of the laborious and time-consuming technique of individual specimen photography to-day almost universally employed (with tinting or whitening of the specimens and subsequent retouching of the prints), Derby's specimens were mounted in cement on boards in exactly the pose and position seen on the finished plates; apparently without further ado, the whole was photographed in bright (sun?) light on a wet plate. After opaque was washed around the individual fossil negatives, the plate numbers were scratched through and the plates were then printed "on plain paper" directly from this negative.

Several works on the Amazonian Carboniferous fauna have appeared since Derby's original study. The largest single contribution was that of Katzer (1903; 1933) in his *Geology of the State of Pará*. He greatly extended the fossil list both by the identification of foreign species and a considerable body of new forms. The paleontological part of this work does not, however, match the general excellence of the geological. In an attempt to compromise between the Carboniferous age assignment of Derby for the Itaituba terrane and the pronouncement of Waagen (1888) as to its Permian age, Katzer applied the "Permocarboniferous" label by which these beds are even to-day not uncommonly known, despite considerable evidence in many publications which supports Derby's original determination.

The history of the studies of the Amazonian terrane and the confusion in extra-Brazilian correlation to be found in these works is so well summarized in the little-known, but excellent, work of Fossa-Mancini (1944) that the following historical survey is a summary translation of his words:

"Near Itaituba, the Tapajós River crosses extensive outcrops of limestone containing silicified brachiopod shells. They weather out abundantly along certain stretches of the river banks; being of such characteristic aspect and often of large size, they quite naturally attracted the attention of the first explorer to pass that way. Thus Silva Coutinho (1863) returned with a collection of fossils from Itaituba. Marcou (1868) published a brief note on this collection, identifying them merely as of Paleozoic age. Agassiz (1869) also dutifully recorded the occurrence, but added nothing more. Likewise Hartt (1870) in the account of his first expeditions in Brazil.

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[2] While this manuscript was in the hands of the editor, the magnificent tribute of the Brazilian Government to the memory of Orville A. Derby on the occasion of his centenary came to hand. In a special publication all of Derby's studies on the Paleontology of Brazil were reprinted, including a fine rendition of Derby's 1874 work on the Itaituba brachiopods, illustrated from the original fossil specimens at Cornell University. ("Orville A. Derby's Studies on the Paleontology of Brazil". Selection and coordination of some of this geologist's out of print and rare works by Alpheu Diniz Gonsalves. Published under the direction of the Executive Commission for the 1st Centenary Commemorating the Birth of Orville A. Derby, and sponsored by the American Embassy of Brazil, Rio de Janeiro, 1952 (1953), Brazil).

"In 1870 and 1871 Hartt and some of his students, including Derby, extended their studies along the Amazon Valley to the Tapajós fossiliferous limestones. They found similar limes and fossils elsewhere in the general area. A collection of the fossils made by Brown in 1872 made possible the indisputable Carboniferous age determination . . .

"The preliminary reports of the Hartt 'Morgan Expedition' appeared in 1874 as the first number of the *Bulletin of the Cornell University*. In this, Hartt analyzed the Carboniferous limestones and proposed the name Itaituba series for them. In the same Bulletin Derby gave an excellent description of the Itaituba brachiopods and pointed up their affinities.

"By 1872 Derby was already aware of the presence of Carboniferous beds on the Trombetas River, across the Amazon from the Tapajós. As a member of the Geological Commission of the Brazilian Empire he visited these outcrops and collected fossils from them in 1876. Derby shortly studied this material and all other Carboniferous fossil materials from the Amazon Valley. By then the fauna numbered more than a hundred forms; more than half the species he found to be identical to 'Coal Measure' (Upper Carboniferous) species of the United States; six species occurred in both the United States and Bolivia. It was inevitable that the fossils of the Tapajós and Trombetas Rivers and elsewhere in the Amazon Valley should be judged of Upper Carboniferous age (Derby, 1877).

"In his study of the fossils of the 'Productus limestone' in the Salt Range of the Punjab, Waagen made critical comparisons with Derby's Amazonian fauna. In 1882 he recognized *Dielasma itaitubense* Derby in the black limestones at the limit between the middle and upper part of the Productus limestone. Waagen was preoccupied with the idea that the Productus terrane must be Permian in age; hence also for him the fossiliferous limestones of the Tapajós, Trombetas, etc., were Permian. Since the striking affinities of the latter to the upper part of the Coal Measures of the United States argued against such an assignment, Waagen (1882, 1889) found himself obliged also to maintain that the upper section of the Coal Measures was assignable to the Permian. Here then is the remote origin of that exaggerated downward extension of the Permian at the expense of the Carboniferous in North America and Asia which has lead to such lamentable confusion in stratigraphic correlations even on other continents.

"Derby restudied the Amazonian fossils in 1894 and reaffirmed their equivalence to faunas of the Upper Coal Measures of Missouri, Arkansas, Iowa and Illinois, and their Upper Carboniferous (rather than Permian) age.

"Katzer carried on the Amazonian stratigraphic and paleontologic work so well begun by Derby. His first work on the subject appeared in 1897. This was followed by his work on the Geology of the State of Pará (1903). This work contains an extensive chapter on the Amazonian Carboniferous and its relation to the Anthracolitic of other continents; an appendix carries descriptions of new and interesting species of Carboniferous fossils from the Amazon area . . . He breaks his fossil-lists down into the assemblages from six separate sites: 1, Tapajós River, between Barreirinha and Brazilia Legal; 2, confluence of the Pitinga and Jamundá Rivers; 3, Trombetas River, between Lake Jacaré and the Great Lake of Arapecú; 4, Curuá River near Praia Grande; 5, Lake Cojubim in the Maecurú valley; 6, Serra Itauajurí near Monte Alegre. The faunas of the Pitinga River and the Itauajurí Serra comprise many brachiopods and few gastropods; in the faunas of the Trombetas and Curuá Rivers and Lake Cojubim brachiopods predominate and pelecypods are also numerous, but gastropods are lacking; in the Tapajós fauna, which is the richest, all three classes are well represented. These differences indicate marked facies changes which add to the difficulty of stratigraphic correlation.

"Katzer's lists appear in a chapter entitled 'Carbon'; however at the end of his foregoing chapter, 'Perm,' he reports a 'fauna of Permian bearing (Einschlag)' in certain sandy lime beds which overlie the limestones of the Maecurú and Curuá Valleys. However he chose to consider their age problematical out of deference to Derby's having identified many characteristically Carboniferous fossils from them. At the time when Katzer wrote, the erroneous ideas of Waagen and Noetling concerning the Permian age of the Productus limestone had already been widely disseminated. Hence the existence of the species *Productus semireticulatus* Martin, *P. cora* d'Orbigny, *P. lineatus* Waagen, *Cleiothyris roissyi* (Leveillé),*Dielasma itaitubense* (Derby), in the Amazonian deposits and the Productus limestone seemed to be a forceful argument against Derby's correlation, and made Katzer reluctant to give up the possibility that at least the upper part of the Amazonian sequence might be of Permian age . . . In the conclusion of his discussion Katzer succinctly stated [the somewhat contradictory opinion] that at the end of the Carboniferous the sea retreated from the Lower Amazon region, never again to cover this vast area (p. 253).

". . . Since the publication of Katzer's book, knowledge of the stratigraphy and paleontology of the Carboniferous of northern Brazil has grown considerably through the work of the Serviço Geológico e Mineralógico of Brazil. The geological reconnaissances of Albuquerque (1922), Carvalho (1926), Avelino de Oliveira (1926) and Moura (1934) have yielded new data on the geological conditions of different parts of the Amazon Valley. To Moura (1938) we are further indebted for a synthesis which was accompanied by a good geologic map of the area concerned (between parallels 0 and 8° and meridians 51°30′ and 60°30′). Cowper-Reed (1933) has studied the Carboniferous fossils from the Urupadi River; Duarte (1936, 1938) those of the Parauarí and Jatapú Rivers. The results of these investigations have fully confirmed the conclusions formulated by Derby in 1877, and moreover have demonstrated the enormous horizontal extent of the Carboniferous marine sediments.

"In some of these recent publications the marine fossiliferous strata of the Amazonian region are simply referred to the 'Upper Carboniferous,' while in others they are specifically referred to the Uralian; in none is the possibility suggested of their being in part Permian. These publications have stressed even more forcefully the affinities to the Upper Carboniferous faunas of Bolivia and the United States. Thus, in the list of Amazon Valley brachiopods given by Duarte (1936) the species in common with North America, Bolivia, Russia and Belgium are 17, 14, 7 and 3, respectively; of the species in common with Russia, two come from the Artinskian; those in common with Belgium come from the black marble of Dinant, which corresponds to the base of the Viséan. Hence the arguments in favor of an Artinskian age are no stronger than those for the Viséan. Moreover, *Productus cora* and *Schizophoria resupinata* of Duarte's list are represented in both the Dinantian and the Artinskian.

"There are reasons to suppose that in the latest part of the Carboniferous the seas extended much further westward than the sites in the states of Pará and Amazonas. An important indication of this is the high proportion of forms common to the Carboniferous faunas of Bolivia and the Amazon Valley; even more significant is a deposit of brachiopod imprints in chert from the Moa River in the Territory of Acre, Brazil. . . . The Moa River is nearer to the fossiliferous Upper Carboniferous outcrops of Huanta, Tarmo and Ambo in Peru than to those of the Tapajós and Trombetas Rivers, etc.

"It is possible that during the latest Carboniferous the sea extended uninterruptedly from the present Amazon Valley to the region to-day occupied by the Parnahiba Valley in the State of Piauí, although Paiva and Miranda (1937) believe that the sedimentation there took place in a basin surrounded on all sides by land, save for three narrow interruptions, toward the East, the South, and the Southwest; this last they supposed to be the one which permitted connection with the 'Andean sea' of that time. Be this as it may, the presence of marine sediments which may belong to the Upper Carboniferous has been unexpectedly revealed by a well-core taken by the Serviço Geológico e Mineralógico of Brazil near Terezina, on the Parnahiba River in the State of Piauí. Duarte (1936) referred the fossils extracted from the core to *Protaster, Lingula, Lingulidiscina, Orbiculoidea, Edmondia, Aviculopecten,* and *Nucula,* but was unable to identify any of them positively with any known species. He said that these fossils indicate a Uralian age. While this conclusion may be correct, and certainly is suggestive, it does not seem to be founded on sufficiently secure data; the presence of forms comparable with *Spirifer opimus, Lingulidiscina missouriensis* and *Lingula carbonaria* and of indeterminable forms of the other mentioned genera, may constitute an indication of age, but could hardly be adduced as exact proof of a Uralian age. In the excellent *Geologia do Brasil* of A. de Oliveira and O. Leonardos (1943) the fossiliferous strata of Piauí are considered the equivalents of those of Itaituba.

"Both in the Piauí and the Itaituba series brachiopods and pelecypods predominate. Correlations with the formations of the Northern Hemisphere would be less difficult if foraminifera of the family Fusulinidae should be encountered and identified in accord with modern criteria.

"Derby (1894) and Katzer (1903) both mention a rare '*Fusulina*' which they had encountered in the Upper Carboniferous limestones of the Tapajós River. More recent authors have, however, contributed nothing further on the subject. It is possible that Derby and Katzer did not refer to *Fusulina, s.s.* Such a determination requires knowledge and techniques unknown when they worked. But we may be sure that the forms observed by Katzer were Fusulinidae of large size. If they had been globular they would have been referred to the genus *Schwagerina* as was the practice prior to the revelations of Douvillé (1906) and Deprat (1903) as to the unsuspected complexity of the internal structure of the foraminifera of this family . . . In view of the fact that the rare Fusulinidae noted by Katzer were associated with corals (such as *Lophophyllum proliferum* and *Rhombopora lepidodendroides*), pelecypods (such as *Pinna peracuta*), and gasteropods (*e.g.*, *Bellerophon carbonarius*), found by Meek (1872) in the light-colored limestones of Nebraska City, and with brachiopods (like *Productus cora, Spirifer condor, Squamularia perplexa, Ambocoelia planoconvexa* and *Hustedia mormoni*), common in the limestones of Yarbichambi, it seems probable to me that the Fusulinidae-bearing limes of the Tapajós correspond to the Gshelian, and that they contain some form of the genus *Triticites,* the external aspect of which is exactly that of a typical *Fusulina.* It would be convenient to have a microscopic examination of oriented sections of the Tapajós foraminifera . . .

"Meanwhile, we can only express the opinion, which has prevailed among Brazilian geologists and paleontologists for several years, that the fossiliferous Anthracolitic sediments in north Brazil belong in their entirety to the Upper Carboniferous, and appear to correspond to the Uralian."

Happily, what seems to be the most significant contribution to the problem of the age of the Amazonas Carboniferous deposits was recently published by Petri (1952) in which he reported the results of precisely the kind of restudy of the rare Tapajós fusulines that Fossa-Mancini urged. The results are not quite what most previous students or commentators would have expected: Petri shows the forms to belong not to *Triticites* as Fossa-Mancini guessed, but to two primitive fusuline genera, *Millerella* and *Fusulinella*. As Petri points out, the former is a primitive genus of the Fusulinidae, known from the Upper Mississippian to the Upper Pennsylvanian; the Mississippian and Pennsylvanian species of the genus are readily distinguished, and the Amazonian forms are allied to the later species complex. The second genus appears in the Middle Pennsylvanian and became extinct in the middle Upper Pennsylvanian. Petri calls attention to the fact that specialists do not accept identifications of *Fusulinella* from the Permian.

It is Petri's apparently sound conclusion that at least the lower third of the Itaituba sequence, *i.e.*, the part containing his fusulines, must be assigned to the Middle Pennsylvanian (Muscovian of Europe; Desmoinesian of the United States). In view of the present evidence of essential unity of the Amazons "Anthracolitic" fauna, despite the absence so far of fusulines from the upper beds, the whole terrane may well be similarly correlated. Although Petri's age assignment is much older than most previous ones, there have been recurrent suggestions of this outcome. In searching out world affinities of the Glass Mountain faunas of Texas, King (1930) questioned the more or less accepted correlation of the Amazonian sequence with the "Carboniferous" of the Bolivian altiplano. Whereas King spotted in the Bolivian terrane conspicious "Permian" affinities, the Amazonian fauna seemed to him to show closer affinity to the *Lower* Pennsylvanian of southwestern United States (e.g., the Naco limestone of the Galiuro Mts. in Arizona). Stoyanow (1936) has reinforced this view of the Amazonian relationships. Thompson (1943) pointed up King's contention as to the bearing of the Bolivian faunas by recording Permian fusulines there. These were further elaborated by Dunbar and Newell (1945, 1946) who assigned the Bolivian Permian to the base of the system (Wolfcampian of the United States; Sakmarian of Russia)[3]. They also showed that the lower third of the altiplano terrane in the Titicaca area is Pennsylvanian. *Fusulinella peruana* (Meyer) in this lower third of the column suggests coevality, if not continuity, with Petri's fusuline fauna.

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[3] So long as the Permian-Pennsylvanian boundary continues to be drawn by a majority of North American stratigraphers at the base of the Wolfcampian, due in the main to the historical causes outlined in the material quoted from Fossa-Mancina, above, such footnotes as this are a courtesy to foreign readers. Happily, it now appears that the north Brazilian section has been definitely removed from this zone of contention.

Wilhelm Kegel (1951) has recently shown that the trilobites of the "Permo-Carboniferous" terrane of the Piauí-Maranhão Basin strongly bespeak close time equivalence with the Tapajós sequence and possess a morphology that pertains to the world Pennsylvanian fauna; he judges the containing beds to be not younger than Westphalian "C", the while leaning toward correlation with the older unit "B" (= Muscovian). This is essentially the age assigned by Petri to the Tapajós beds on the basis of his fusulines. Thus two decisive blows have been struck at the unfortunate recrudesence of a tendency (*e.g.*, Plummer, Price and Gomes, 1946; Campbell, Almeida and Oliveira Silva, 1949) to refer the Piauí sequence, and by implication the commonly correlated Amazonian terrane, to the "Permo-Carboniferous".

Whether this term is applicable to any Brazilian terrane is still an open question; however, evidence mounts (*e.g.*, Caster, 1952) for considering still more of the coal, glacial and limited marine beds of south Brazil as Pennsylvanian. Kegel and Texeira da Costa (1951) furnish data on the fasciculate-ribbed aviculopectinid pelecypods common to the Carboniferous fauna of the Maranhão Basin and the Itararé series from the inter-glacial beds of Taió, Santa Catarina in the Paraná Basin. These fossils suggest not only coevality of these deposits of the two basins, but also correlation with Pennsylvanian faunas of North America. The flora of the post-glacial part of the "Permo-carboniferous" terrane in the Paraná Basin bespeaks ever more strongly *Permian* age, however, as Mendes (1952) has pointed out in his restudy of the unique, apparently autochthonous and non-correlatable pelecypod fauna of these beds.

(See combined Bibliography at end of Dresser's paper.)

B. NOTES ON SOME BRACHIOPODS FROM THE ITAITUBA FORMATION (PENNSYLVANIAN) OF THE TAPAJÓS RIVER, BRAZIL[1]

Hugh Dresser
Carter Oil Company

ABSTRACT

Twelve species and one variant of brachiopods belonging to ten genera and one subgenus, are identified and described from the Carboniferous Itaituba formation of the Tapajós River, a tributary of the Amazon River in Brazil. They represent about one-third of the brachiopods of the fauna and only a small portion of the entire fauna. One genus, three species, and one variant are new. Seven of the species occur in other parts of the world; they appear to indicate a Pennsylvanian age for the Itaituba formation.

INTRODUCTION AND ACKNOWLEDGMENTS

The purpose of this paper is to examine some of the brachiopods of the Carboniferous Itaituba formation from the Rio Tapajós, a tributary of the Amazon, and to identify and redescribe them in the light of information which has been published since the first description of the brachiopods of this fauna by Derby in 1874. It is hoped that the age determination of such of the brachiopods as are known outside the Amazon area will add a link to the chain of evidence concerning the still-debated age of the Itaituba formation.

Twelve species and one variant of brachiopods belonging to ten genera and one subgenus have been studied. Of them, the variant, three species and one genus are new; six species have been placed in different genera from those assigned to them by Derby, and one has had its specific assignment changed. Only two species were left nomenclatorially as Derby described them.

The writer is indebted to Dr. Kenneth E. Caster for his generous aid and assistance on perplexing problems which have arisen during the preparation of this paper; for his aid in the translation of pertinent French and Brazilian literature as the needs arose, and for giving the author this opportunity to "cut his paleontologic teeth." Dr. Caster has already expressed our joint appreciation to the many

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[1] Based on a dissertation submitted to the Graduate School of Arts and Sciences of the University of Cincinnati in partial fulfillment of the requirements for the degree of Master of Science, 1951.

Brazilian sources of indebtedness and to Dr. W. Storrs Cole of Cornell University for making copies of the Derby illustrations of the Tapajós fauna. The text figures were prepared by Mrs. Elizabeth A. Dalvé and part of the costs of the revision of the manuscript and printing of the plates was met by research funds from the Graduate School of Arts and Sciences of the University of Cincinnati.

PREPARATION OF MATERIAL

In the summer of 1948 Dr. K. E. Caster collected naturally etched, silicified fossils, and muddy limestone blocks containing silicified fossils from the Tapajós limestone. This is the type area of the Itaituba formation (Igarapé Bom Jardim, a small tributary of the Tapajós River, two km. above Itaituba, in the state of Pará, Brazil).

More than nine months were spent etching the fossils from the limestone blocks and in perfecting equipment wherewith it could be done efficiently. About three-fourths of the material has been etched. This would have been a relatively simple and quick process but for the extremely bituminous and muddy nature of the limestone. To etch a limestone block completely is an almost impossible task, since all of the mud would have to be removed during etching. No completely satisfactory method has yet been devised for doing this.

The limestone blocks themselves are light grey on fresh fracture, weathering to dark grey or brown. They contain about fifty per cent calcium carbonate, about twenty-five per cent black-brown petroliferous mud, and about twenty-five per cent silicious material. The silicious material occurs mostly as chert nodules and lenses, but some of it occurs as microscopic quartz crystals disseminated through the rock. The calcium carbonate of the fossil shells appears to have been silicified by a crystal-for-crystal replacement. After etching, many of the fossils with thick shells reveal a network of quartz crystals on the interior. This is due to the incomplete silicification of the internal portions of the shell, the network effect being caused by the removal of calcium carbonate from between the quartz crystals during etching. The black-brown petroliferous mud is generally sticky, sometimes flaky. It is rather evenly distributed throughout the rock.

As indicated by the fragmental nature of much of the fossil material, the environment of deposition was evidently in a sea shallow

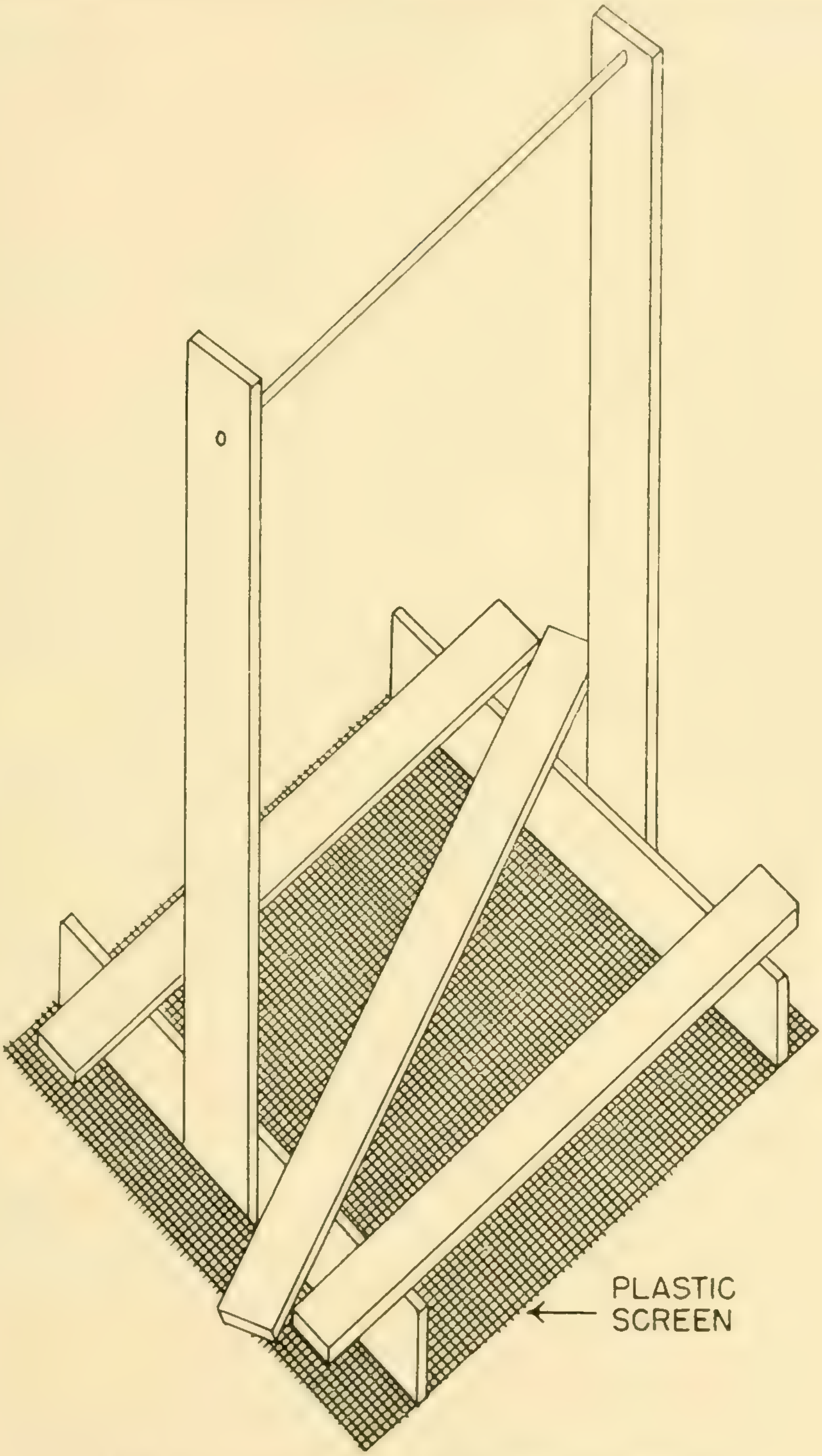

FIG. I — LUCITE ETCHING TRAY

Fig. 1. Sketch of a plexiglass and plastic screen acid-resisting etching rack for treatment of small, differentially silicified blocks of limestone.

enough for the waves to wash the shells around and break them up. This type of environment is also indicated by the fact that while the shells generally lie flat, paralleling the bedding, they may occasionally stand at an angle to it, suggesting current action.

The equipment for etching, which was developed by trial and error, is both economical and reasonably efficient. It consists of nine five-gallon stone "pickle jars," eight plastic trays for holding blocks and fossils, a plastic sorting pan, stone sink, fifteen feet of plastic tubing, and many carboys of muriatic acid.

The five-gallon stone jars were lined with a quarter-inch coating of paraffin to prevent seepage through the pottery. The plastic trays designed to hold the fossils are constructed from plexiglass[2] and ordinary commercial plastic window screening. The plexiglass sheets were sawed into the proper lengths and widths and then fused together by the solvent ethylene chloride. The plastic screening was cemented to the plexiglass frame with ethylene chloride. The finished rack is shown in Fig. 1.

The plexiglass pieces were soaked in the solvent for from three-quarters of a minute to a minute and a half, or the ethylene chloride was liberally applied with a brush. It has been found that a better bond is produced if some pulverized plexiglass is added to the ethylene chloride until it becomes a rather thick and viscous cement. It should be remembered in working with ethylene chloride that it is poisonous and quite volatile. Therefore, all work should be carried on in a well ventilated room, or under a chemical hood.

The "Lucite" pieces were welded together by applying the ethylene chloride liberally to both surfaces and then holding them together for two or three minutes, or until a temporary bond was produced. These joined parts were cemented to other parts until the whole tray was completed except for the cementing of the screen to the bottom. The whole tray was allowed to stand overnight for the joints to weld completely. The plastic screening was then cemented to the bottom of the tray, and allowed to dry for at least four hours before any strain was placed upon it.

The jars were filled from one-half to two-thirds with water, and the trays bearing the limestone blocks were placed in them. Acid was then siphoned to the vats until the limestone was vigorously effervescing.

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[2] Dupont "Lucite," an acrylic resin.

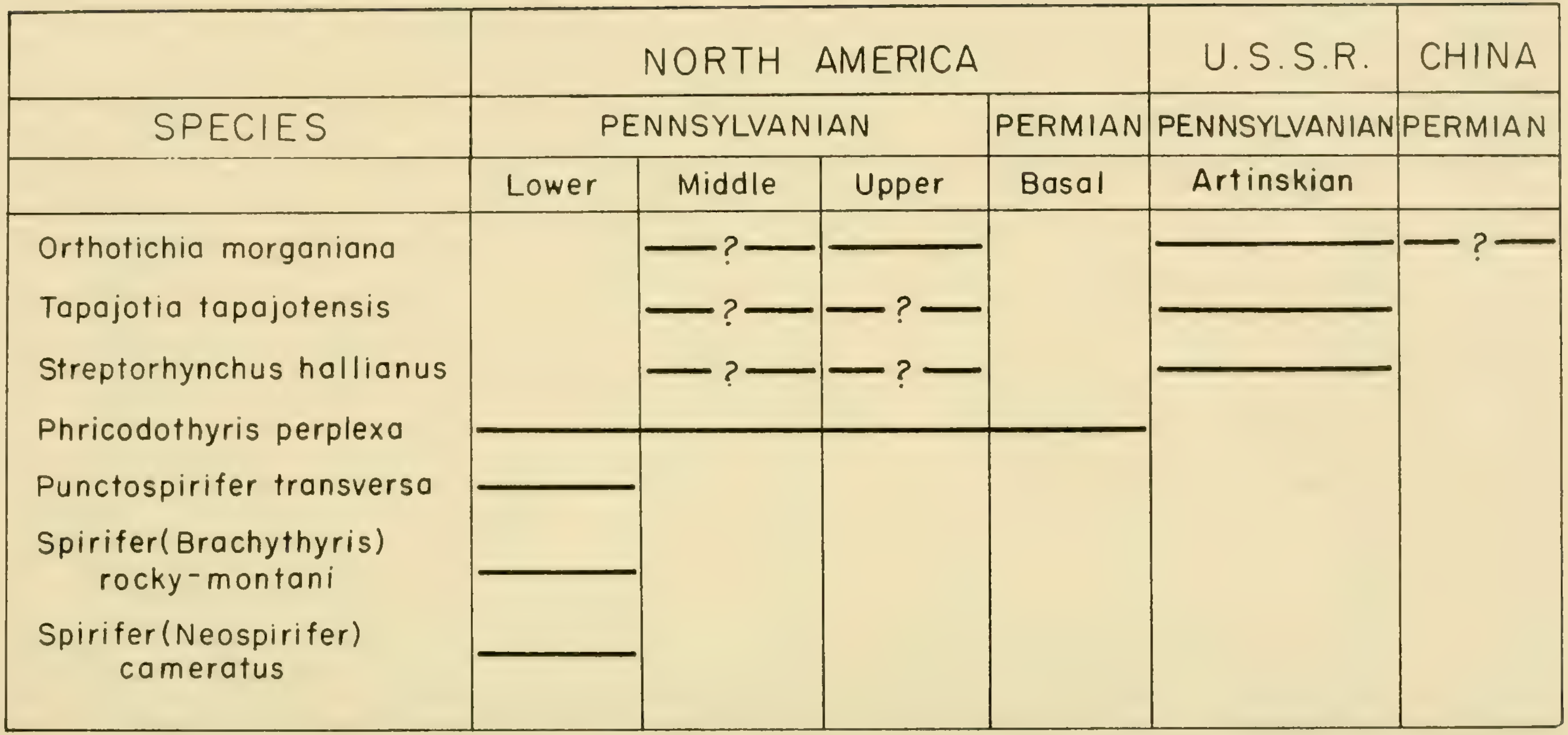
When the effervescence ceased, more acid was added until the limestone again effervesced. By the time this second effervescence ended, the mud usually had to be removed from the surfaces of the block before effervescence could again be induced. To remove the muddy residue from the blocks the plastic tray was lifted out and placed in a plastic pan with sides about two inches high. The loose mud was then hosed off and the limestone block lifted out with care lest partially liberated shells be damaged, and the loose fossils were removed from the screen. The fine residue, consisting largely of scraps, was washed into a beaker. Often the sticky mud on the limestone block had to be very carefully picked off with a probe or dissecting needle, before the block could be returned to the acid bath and effervescence induced.

This procedure may be repeated as often as desired. However, with the Tapajós material after the second time, more residue removal work was required than the fossil returns seemed to justify. When there were still visible fossils in the rock, the vibro-tool or a hammer and chisel were used to chip them out for further cleaning.

After several blocks had been treated there was usually so much mud in suspension in the acid that its slow settling onto specimens effectively stopped the etching. The mud was then allowed to settle for a day or so and the clear acid was siphoned off to be used again. The residue in the vat was washed into the plastic pan, and the mud decanted. The microfossils in the remaining material were then picked out and fragmental material was allowed to dry on paper toweling over night. This material was then sieved in water, and the various grade sizes examined for microfossils.

PALEONTOLOGY

The total Itaituba fauna reclaimed from the acid bath, plus the extensive collection of naturally etched material from the weathered outcrops, is large. Less than one-tenth of the whole is here considered.



SPECIES	NORTH AMERICA				U.S.S.R.	CHINA
	PENNSYLVANIAN			PERMIAN	PENNSYLVANIAN	PERMIAN
	Lower	Middle	Upper	Basal	Artinskian	
Orthotichia morganiana		—?—	——		——	—?—
Tapajotia tapajotensis		—?—	—?—		——	
Streptorhynchus hallianus		—?—	—?—		——	
Phricodothyris perplexa	——	——	——	——		
Punctospirifer transversa	——					
Spirifer(Brachythyris) rocky-montani	——					
Spirifer(Neospirifer) cameratus	——					

Fig. 2. Geologic and geographic distribution of critical brachiopods in the Amazonian Carboniferous.

SYSTEMATIC DESCRIPTIONS

Order **PROTREMATA** Beecher, 1891

Suborder **ORTHOIDEA** Schuchert and Cooper, 1932

Family **RHIPIDOMELLIDAE** Schuchert, 1913

Genus **RHIPIDOMELLA** Oehlert, 1890

Type species.—*Terebratula michelini* Léveille, Soc. Géol. France, Mém., vol. 2, 1835, p. 34, pl. 2, figs. 14-17.

As abstracted from Hall and Clarke (1892, p. 209, 210), the features of this genus are as follows: shells subcircular in outline, biconvex and sublenticular; ornament consists of fine, rounded, subequal costellae which are hollow, often opening upon the surface. In the ventral valve there are large flabelliform, medially divided, diductor muscle scars. The adductors occupy a small central scar completely enveloped by the great diductors. The muscular area is bordered by two strong teeth from the base of which a strongly defined curving ridge extends forward. The pedicle scar fills the entire rostral cavity. In the dorsal valve there are deep, narrow dental sockets and extremely prominent crural plates sometimes supporting short crura. The cardinal process is erect, strongly arched on its anterior face, and with a trilobed posterior face. The muscular area is quadruplicate, comparatively small and usually indistinct. A broad, low median ridge extends anteriorly about half the length of the valve from the base of the cardinal process.

In addition, Schuchert and Cooper (1932, p. 135) demonstrated that *Rhipidomella* has a definite interarea between the two halves, as contrasted with *Peritocardinia* Schuchert and Cooper, 1932, which is similar, but has the interarea completely reduced. In *Perditocardinia* the ventral beak often overlaps the dorsal beak to such an extent as to produce a rostrate appearance, as in *Terebratulina.*

The Tapajós specimens have a very definite interarea between the two valves, and agree closely with Hall and Clarke's analysis of *Rhipidomella.* They differ in having a strongly elevated notothyrial platform from which the cardinal process arises; the dorsal musculature is also deeply impressed and well defined.

Rhipidomella penniana (Derby) Pl. 1, figs. 1-4, 6-7

1874. *Orthis penniana* Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2. p. 23, pl. 5, figs. 13, 15, 17, 19-22; pl. 8, fig. 2.

1903. *Rhipidomella penniana* (Derby), Katzer, Grundzuge de Geologie des Unteren Amazonas Gebietes (des Staates Pará in Brasilien), p. 172, pl. 6, fig. 9a-c; (Geologia do Estado do Pará, 1933, p. 153, pl. 6, fig. 9).
1914 (?). *Rhipidomella cora* (d'Orbigny), Kozłowski, Annales de Paléontologie, vol. 9, p. 48, fig. 15, pl. figs. 35-60.
1929 (?). *Rhipidomella cora* (d'Orbigny), Steinmann, Geologie von Peru, p. 49, fig. 45.
1933. (?) *Orthis (Rhipidomella) penniana* Derby, Reed, Ann. Mag. Nat. Hist., vol. 11 (10), p. 527.
1938. *Rhipidomella penniana* (Derby), Duarte, Serv. Geol. Min. (Brazil), Bol. 84, p. 13, pl. 2, figs. 2, 3.

The new Tapajós material examined agrees perfectly with Derby's description of this species. The important features of the species are: thick, heavy valves; subtrigonal outline, biconvex with the dorsal valve being the more convex; vertical delthyrium is nearly filled by the projecting cardinal process of the dorsal valve; notothyrium about equal in size to the delthyrium, and lies at right angles to it (horizontally). It is completely filled by the cardinal process. The surface of the valves is marked by fine rounded costae and numerous lines of growth. Many of the large specimens develop a slight median sinus on each valve, one opposing the other, giving the shell a more or less heart-shaped appearance. The dorsal sinus is the more prominent. In the ventral valve large, widely divergent teeth enclose the pedicle muscle scar between them and the beak. The diductor muscle scars are elongated and flabelliform, completely enclosing a narrow, medially divided ridge upon which the adductors are situated. In the dorsal valve the cardinal process is situated upon

Dimensions.— Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm.)
25258	18.	18	11
25258	21.	19	13
25258	20.	19	12
25258	19.	18.5	12.5
25258	19.	19	9
25258	18.	15	11
25258	17.	14	10
v.v. 25258	19.	17	5
v.v. 25258	20.	18	5
d.v. 25258	20.	20	8
d.v. 25258	17.	15	5

a high notothyrial platform. Its posterior face has a trilobed appearance. The crura arise from the anterolateral margins of the notothyrial platform just anterior to and mediad of the sockets which are situated between the notothyrial platform and the posterior margin of the shell. The four muscle scars are well impressed, the posterior set being impressed into the anterior portion of the notothyrial platform. A broad median ridge, which divides the muscle scars, extends almost to the middle of the valve.

Comparison.—This species differs from North American species of *Rhipidomella* in the following ways: *R. penniana* possesses a very high notothyrial platform from which the cardinal process arises. The muscle scars of the dorsal valve are deeply impressed, the posterior set being partially impressed into the anterior portion of the notothyrial platform.

Kozłowski (1914, p. 48) has identified a *Rhipidomella* from the Carboniferous of Bolivia as D'Orbigny's *R. cora*. However, his text figures and his description of this form lead one to believe that it may be Derby's species, *R. penniana*. Since his text figures show only exteriors, they do not help much, and until the Bolivian fauna is restudied, the identification must remain doubtful. Steinmann is apparently following Kozłowski in identifying the Peruvian Rhipidomellas as *R. cora*.

Reed (1933) reports that Haug had an apparently conspecific shell from the Pennsylvanian of the Sahara which Haug identified, however, as *R. michelini* Léveille.

Number of Specimens Studied.—About 850 specimens consisting mainly of dissociated dorsal and ventral valves were studied.

Family **SCHIZOPHORIIDAE** Schuchert, 1929

Subfamily **SCHIZOPHORIINAE** Schuchert, 1929

Genus **ORTHOTICHIA** Hall and Clarke, 1892

Type species.—*Orthis* (?) *morganiana* Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2, 1874, pp. 29-32, pl. 3, figs. 1-7, 9, 11, 34; pl. 4, figs. 6, 14, 15. Itaituba formation, Carboniferous of Brazil.

As abstracted from Hall and Clarke (1892, p. 213), the characters of this genus are as follows: in the ventral valve there is a thin, elevated median septum dividing the muscular area. It has prominent, vertical dental lamellae. The muscular area is but faintly impressed and faintly defined at its anterior border. In the dorsal valve there is a multipartite cardinal process. The muscle scars are in three pairs, arranged as in *Schizophoria.*

Comparison.—Externally this genus often resembles *Schizophoria,* but it can be distinguished from *Schizophoria* if good interiors are available. *Schizophoria* does not have the well-developed ventral median septum of *Orthotichia.*

The Tapajós material is of the type species of the genus. It agrees in every respect with the generic diagnosis given by Hall and Clarke.

Orthotichia morganiana (Derby) Pl. 1, figs. 8-11, 13

1874. *Orthis* (?) *morganiana* Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2, pp. 29-32, pl. 3, figs. 1-7, 9, 11, 34; pl. 4, figs. 6, 14, 15.
1892. *Orthotichia morganiana* (Derby), Hall and Clarke, Paleontology of New York, vol. 8, pt. 1, p. 213, pl. 7, figs. 11-15.
1894. *Orthis morganiana* Derby, Derby, Jour. Geol. vol. 2, p. 492.
1903. *Orthotichia morganiana* (Derby), Katzer, Grundzuge de Geologie des Unteren Amazonas Gebietes (des Staates Pará in Brazilien), p. 164, pl. 5, fig. 6a-f; (= Geologia do Estado do Pará, 1933, p. 153, pl. 5, fig. 6.)
1914. *Orthotichia morgani* (Derby), Kozłowski, Annales de Paléontologie, vol. 9, p. 62, pl. 3, figs. 11-12.
1927 (?). *Orthotichia morganiana* (Derby), Chao, Geol. Soc. China, Bull., vol. 8, p. 99, pl. 1, fig. 11; pl. 2, figs. 2, 3.
1927 (?) *Orthotichia morganiana* Derby mut. *chihsiaensis* Chao, Geol. Soc. China, Bull., vol. 6, pl. 101, pl. 2, fig. 4.
1930 (non). *Orthotichia kozlowskii* King, Univ. Texas, Bull., No. 3042, pp. 36, 45, pl. 1, figs. 14, 15.
1938. *Orthotichia morganiana* (Derby), Duarte, Serv. Geol. Min. (Brazil), Bol. 85, p. 11, pl. 1, figs. 1, 2.

This species is characterized by the following: its large size; the broad sinus in the ventral valve of old specimens; the non-alternate, regular character of the striae making up the ornament; the hinge line length equals about half the width of the shell; beaks of both valves are moderately to slightly incurved, not erect.

Exterior.—Well-preserved, undistorted specimens are nearly circular in outline, and are biconvex with the dorsal valve slightly more inflated than the ventral. On old specimens there is a broad, shallow sinus developed in the ventral valve, near its anterior margin, which indents the dorsal valve. Thus, the shell is uniplicate. Derby (1874, p. 29) stated that there is a strong ventral sinus which indents deeply into the dorsal valve. None of the specimens studied show so prominent a sinus.

The beak of the ventral valve is somewhat moderately incurved over a delthyrium which is about as high as it is wide. That of the dorsal valve is slightly incurved over a notothyrium which is about half as high as it is wide. The length of the hinge line is about half the width of the shell.

The ornament consists of fine, radiating striae which multiply by bifurcation and which number about six per millimeter at the anterior margin. Sometimes these striae terminate abruptly as a small, round hole, the striation probably continuing out as a small, hollow spine. An occasional growth line is also often present.

Interior.—Arising just in front of the beak in the ventral valve is a thin, elevated median septum which extends forward from one-third to one-half the length of the valve. Near its anterior extremity it rises to a sharp, elevated point. The small, divergent teeth are supported by thin dental plates which extend forward, nearly parallel to the median septum, for about one-fourth the length of the valve. Laterally they delimit the faintly impressed, oblong muscle scars on either side of the median septum.

In the dorsal valve there are three sets of muscle scars which are completely surrounded by the anterior extensions of the crural plates. The muscle area is further divided by a definite, low, median ridge having its origin under the beak and terminating where it joins the anterior extensions of the crural plates. It is considerably more elevated anteriorly, near its termination, than it is posteriorly. Two of the three pairs of muscle scars are oval in outline, and are located in the normal position in the posteromedian portion of the valve with the low, median ridge dividing them. The anterior pair is the better impressed of the two, the posterior pair having boundaries which are quite indistinct. The third pair of muscle scars is likewise oblong, and it lies laterad of the posterior pair just described. Each scar of this pair lies just under the crural plates at the place where they change from plates into the ridges bordering the muscular area. In well-preserved specimens there is a suggestion of a callus dividing each scar of this pair into equal, lateral halves.

The crural plates are wide and divergent, and they project ventrally, staying rather close to the beak, into toothlike processes, the crural processes. The cardinal process is multilobed and small, situated in the apex of the beak. Sometimes it appears to be unilobed due to the etching away of the other lobes.

Dimensions.— Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm.)
25259	40.	35	26 distorted
v.v. 25259	17.	17	6 distorted
d.v. 25259	31.	27	10 distorted

Accurate measurements were difficult to obtain because all the large specimens were distorted. The shape of the small specimens is not diagnostic.

Comparison.—Chao (1927, pp. 99-101) has described this species as occurring in the Permian of China. His descriptions and plates do not permit evaluation of his identification. He evidently did not have any good interiors of the valves, and, therefore, his generic determinations may be questioned. Perhaps this is an example of homeomorphy between species of two genera.

R. E. King (1930, p. 36, 45), in his study of the Permian of the Glass Mountains of Texas, believed that he had brachiopods conspecific with those from Bolivia which Kozłowski (1914, p. 62) had labeled *Orthotichia morgani (sic)* Derby (= *Orthotichia morganiana).* However, King believed the Bolivian species was incorrectly identified by Kozłowski with the Amazon species. Hence, when he proposed the new specific name *Orthotichia kozłowski* for his Texas Permian material, he placed Kozłowski's *O.* "*morgani*" in synonymy with it. King's *O. kozłowski* from the Texas Permian is especially distinct from true *O. morganiana,* since it possesses plates running transversely between the dental lamellae and the median septum at their anterior extremities, and *O. morganiana* Derby possesses no such structure. However, I believe King was in error in supposing that the material identified by Kozłowski as *O.* "*morgani*" is the same as his *O. kozłowskii.* In the first place, Kozłowski (1914, p. 62) stated that his material fits the type descriptions of *O. morganiana* in every way. In the second place I believe that King placed Kozłowski's material in his species because it has a shallower sinus in the ventral valve than Derby (1874, pp. 29-32) stated that his type material possessed. However, the topotypes of *O. morganiana,* which are here described, reveal no such deep sinus as Derby indicates. Perhaps Derby was misled by the distortion, so common in this species, which makes the sinus appear deeper than it really is. For these reasons it seems likely that the fossils identified by Kozlowski as *O.* "*morgani*" Derby are specifically identical with Derby's species, *O. morganiana,* and not with King's *O. kozlowskii.*

Stoyanow (1926) reported *O. morganiana* from the upper portion of the Pennsylvanian section in the Galiuro Mts. of Arizona. There is some doubt whether the horizon is Middle or Upper Pennsylvanian. The Lower Pennsylvanian is, however, well developed below the *O. morganiana* horizon. Stoyanow also reported that Tschernyschew identified this species in the Upper Pennsylvanian *Schwagerina* limestone of the Urals.

Number of Specimens Studied.—About 120 specimens, mostly of dissociated dorsal and ventral valves, were studied.

Superfamily **STROPHOMENACEA** Schuchert, 1896

Family **STROPHOMENIDAE** King, 1846

Subfamily **ORTHOTETINAE** Waagen, 1884

Genus **STREPTORHYNCHUS** King, 1850

Type species.—*Terebratula pelargonatus* Schlotheim, Akad. Munich, vol. 6, 1816, pp. 28, 29, pl. 8, figs. 21-24. The Shell limestone and breccia of Great Britain.

The genus *Streptorhynchus,* as defined by King, includes those members of the Orthotetinae which lack a ventral medial septum and which have the dental plates but little developed. These dental plates are most strongly developed where the teeth join the palintrope, and they become less and less prominent as they are traced downward toward the beak.

In the Tapajós material the dental plates take more the form of a callus than of a plate or ridge. This is typical of the small extent to which they are developed in this genus.

Streptorhynchus hallianus Derby Pl. 1, fig. 5; Pl. 8, figs. 2,3,5,6

1874. *Streptorhynchus hallianus* Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2, p. 35, pl. 5, figs. 1, 2, 5, 8, 12, 14, 16, 18; pl. 8, fig. 3.
1894. *Streptorhynchus hallianus* Derby, Derby, Jour. Geol., vol. 2, p. 492.
1903. *Streptorhynchus hallianus* Derby, Katzer, Grundzuge de Geologie des Unteren Amazonas Gebietes (des Staates Pará in Brasilien), p. 172, pl. 6, fig. 6a-1; (= Geologia do Estado do Pará, 1933, p. 153, pl. 6, fig. 6.)

1938. *Streptorhynchus hallianus* Derby, Duarte, Serv. Geol. Min. (Brazil), Bol. 84, p. 19, pl. 5, figs. 3, 4; pl. 6, fig. 1.

The material upon which the diagnosis of this species is based consists of the posterior portions of four dorsal valves and one complete and one nearly complete ventral valve. The diagnosis is as follows: hinge line is about two-thirds as long as the shell is wide; anterior edge of the shell has radial plications bearing costae which number from 10 to 12 per 5 mm. at that point. The plications do not extend far posteriorly. The muscle scar of the ventral interior is bordered by an irregular, sometimes faint callous just anterior to which the internal surface of the valve is irregularly pitted. The muscle scars are not well separated, but there appears to be a faint trace of a narrow, medial scar for the attachment of the adductors. The teeth are strong, straight, and divergent. They are supported by a dental callus which becomes obsolescent before it reaches the beak. The cardinal process is a long, bifid structure with a deep groove running down the exterior face from the sinus between the lobes to the beak. Each lobe is again grooved at the tip, sometimes by more than one groove. The muscle scars of the dorsal valve are partially surrounded by the anterior extensions of the crural plates as a callus which terminates somewhat posterior to the anterior edge of the muscle scars. They are divided by a low median ridge leaving each scar as an ovate impression without division into anterior and posterior sets.

Dimensions.— Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm.)
v.v. 25260	26.	27	11

Comparison.—The dorsal valves of this form look much like those of *Derbyia correanus* (Derby). However, they can be distinguished since each lobe of the cardinal process of *Streptorhynchus hallianus* is grooved only at the tip, the grooves not extending as far toward the beak as in *D. correanus*. Sometimes there is more than one groove at the end of each lobe in *S. hallianus*. There is a low, prominent medial ridge dividing the dorsal muscle scars of *S. hallianus*. This ridge is weak or absent in *D. correanus*. The muscle scars of *S. hallianus* are much better impressed than those of *D. correanus*.

As far as can be determined, *D. correanus* never has its anterior margin thrown into plications. This may be a useful character in distinguishing between the exteriors of the two forms. The differences between the ventral valves of the two species are obvious. The ventral valves of *D. correanus* have a ventral medial septum; those of *S. hallianus* do not.

Stoyanow (1926) reports this species from the upper portion of the Pennsylvanian column of the Galiuro Mts. of Arizona; this may be either Middle or Upper Pennsylvanian. He also reports that Tschernyschew had identified the species from the "Cora" limestone (Upper Pennsylvanian) of the Urals.

Number of Specimens Studied.—Six specimens were studied. They consisted of 4 incomplete dorsal valves (the posterior portions); one complete ventral valve; and one incomplete ventral valve (the posterior portion).

Genus **DERBYIA** Waagen, 1884

Genolectotype.—Derbyia regularis Waagen, Hall and Clarke, Paleontology of New York, vol. 8, Pt. 1, 1892, p. 262. Upper Productus limestone (Permian) of India.

Waagen (1884, pp. 591-594) defined the genus *Derbyia* as including those forms with the following characteristics: the external appearance is the same as that of the genus *Streptorhynchus*. In the dorsal valve there is an extremely large and massive, bifid cardinal process. The crural plates partially surround the muscular area. The impressions are always large and deep but not separated from each other by a median septum. In the ventral valve the strong median septum extends from the apex of the beak about halfway to the anterior margin. The hinge teeth are supported inside the area by prominent ridges which extend to the apex where they unite with the median septum. This group is known as the *Septati*. The hinge teeth may be supported inside the area by dental plates which unite with the posterior edge of the median septum throughout their length, "forming a little trigonal chamber under the vaulted pseudodeltidium." This group is known as the *Camerati*.

Thus, Waagen divided *Derbyia* into two groups, the *Camerati* and the *Septati*. The *Camerati* are those with the "little trigonal chamber" formed by the union of the dental lamellae with the median septum throughout their length, thus producing a spondylium.

The *Septati* are those in which the dental lamellae have been reduced to mere columns confluent with the teeth and joining the median septum only at the apex of the ventral valve.

Since the type species of *Derbyia, Derbyia regularis* Waagen, is a member of the *Septati,* Girty (1908, p. 190) has split the group *Camerati* from the genus *Derbyia* and made it synonomous with the genus *Orthotetes.* The early descriptions of *Orthotetes* by Fischer de Waldheim (1820, 1837, 1850) are indistinct, and it seems safe to assume that he had no clear idea of its structure. Girty believed that what Fischer de Waldheim was calling a dorsal valve with septa was actually a ventral valve. Waagen (1884, pp. 592, 607) in proposing the genus *Derbyia,* and in his analysis of *Orthotetes,* agreed with Fischer de Waldheim's interpretation of the forms, *i.e.,* septa are present in the dorsal valve and none are present in the ventral valve. Girty's case appears best founded for the following reason: in Fischer de Waldheim's 1850 paper he figured a species closely related to the type species which clearly shows the presence of septa in the ventral valve. Therefore, Girty's definition of *Orthotetes* as being synonomous with the *Camerati* of Waagen's *Derbyia* seems best. This restricts the genus *Derbyia* to the *Septati* of Waagen. Thus, the genus *Orthotetes* possesses a small spondylium, whereas the genus *Derbyia* possesses obsolete dental lamellae joined with the median septum only at the apex of the beak.

The Tapajós specimens agree essentially with Waagen's original description of *Derbyia* as modified by Girty. However, the Tapajós material does differ in that the dorsal musculature of *D. correanus* is often divided by a faint median ridge, and it is not deeply impressed.

Derbyia correanus (Derby) Pl. 1, fig. 12; Pl. 2, figs. 1-6

1874. *Streptorhynchus correanus* Derby, Cornell Univ., Sci., Bull., vol. 1, No. 2, pp. 32-35, pl. 6, fig. 11; pl. 7, figs. 1-4, 8, 10-14, 17.

1894. *Streptorhynchus correanus* Derby, Derby, Jour. Geol., vol. 2, p. 492.

1938. *Orthotetes correanus* (Derby), Duarte, Serv. Geol. e Min. (Brazil), Bol. 84, p. 16, pl. 4. fig. 5.

No specimens complete enough to permit an adequate description of the exterior form of this species are available. However, this is not an insurmountable obstacle in identification, for as Dunbar and Condra (1932, p. 77) have pointed out, there is an unusual amount of individual variation in the shape of the Upper Carboniferous Derbyias. Concerning the shape of the Tapajós material, only the following can be said; the ventral beak varies from being high and distorted to only about half as high as the hinge line is wide and undistorted; the hinge line is about one-half to two-thirds the width of the shell; the dorsal valves are generally quite regularly convex.

The ornament consists of radiating costae interrupted at regular intervals by obscure to prominent growth lines. When these growth lines are abundant and prominent, they give the shell a crenulated appearance. The costae multiply largely by intercalation, and they are a little narrower than the flat-bottomed spaces between them.

The interior of the ventral valve has two strong, diverging teeth, each of which is continued along the inside edge of the delthyrium as a strong callus to unite with the median septum just above the apex of the beak. This septum continues anteriorly for about one-third the length of the valve.

The internal face of the deltidium bears a weak median callus which fits into the groove between the lobes of the bifid cardinal process of the dorsal valve when the two valves are articulated. On well-preserved specimens two small depressions can be seen on either side of this callus at the apex of the deltidium where the teeth join the median septum. These depressions are undoubtedly for the reception of the ends of the lobes of the cardinal process.

The muscle scars of the ventral valve are too obscure to describe.

In the dorsal valve the oval muscle scars lie directly under the cardinal process and between the anterior extensions of the crural plates. In some specimens they are divided by a faint median ridge. There is no division into anterior and posterior pairs.

The cardinal process is a long, bifid structure which bends posteriorly to various degrees depending upon the angle of the area of the corresponding ventral valve. The exterior of each lobe of the bifid cardinal process has a groove running from its tip almost to the beak of the valve. There is also another groove extending from the cleft between the two lobes to the beak of the valve. These grooves probably served for the attachment of the diductor muscles. On the interior of the cardinal process, just below the median cleft between the two lobes, is a slight callus which sometimes extends completely to the apex of the beak. Laterally the cardinal process gives rise to a pair of anteriorly diverging crural plates which partially surround the posterior portions of the muscle scars. Well-defined, deep sockets are located between the posterior portions of the crural plates and the hinge line.

In his description of the species Derby (1874, p. 33) stated that the "strongly developed dental plates" are united with the median septum "*within the apex of the beak,*" forming a "*small* conical cavity . . . *within the beak.*" None of the Orthotetinae here studied have any suggestion of a spondylium. In view of this, Derby has been interpreted as referring to the tiny depression formed where the ventral ends of the dental calluses join the posterior end of the median septum. This depression is extremely small, and it could not be construed as a spondylium. Furthermore, Derby's illustrations of his species do not show a spondylium.

Diagnosis.—This species is characterized by the following: the presence of a single groove extending down each lobe of the bifid cardinal process almost to the beak; the poor definition and light impression of the muscle scars; the presence, in some specimens, of a faint median ridge dividing the muscle scar into equal, lateral halves; the joining of the ventral median septum to the obsolescent dental lamellae *just above* the apex of the beak, and not *within* the apex of the beak.

Approximate (restored) Dimensions.—

Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm.)
25261	50	55	17
d.v. 25261	50	58	17
v.v. 25261	20	25	7
v.v. 25261	28	30	4

Comparison.—See discussion under the heading of *Comparison* in the discussion of *Streptorhynchus hallianus.*

Number of Specimens Studied.—Twenty-one specimens of mostly dissociated, incomplete dorsal and ventral valves were studied.

Genus **TAPAJOTIA** Dresser, n. gen.

Type species.— *Streptorhynchus tapajotensis* Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2, 1874, p. 37, pl. 5, figs. 3, 6, 7, 8, 9, 10; pl. 8, fig. 9.

The shells of this new genus are moderately to weakly resupinate. The hinge line is long. The cardinal area is low and the beak is not cemented. The ornament consists of radially arranged costae as in *Derbyia* and *Streptorhynchus*.

The dental lamellae are reduced to mere calluses bordering the interior edges of the delthyrium. The median septum is likewise reduced to a small plate less than 1 mm. high and 5 mm. long in large specimens.

In the dorsal valve the free edges of the crural plates are recurved posteriorly to such an extent that their proximal portions are actually coalesced with the ventrolateral edges of the chilidium forming two tubes, one on each side, whose long axes project laterally and somewhat anteriorly. The distal portions of the crural plates continue nearly parallel with the hinge line, but they are not recurved as much as the proximal portions. They bound spoon-shaped sockets which are the lateral continuations of the tubes formed by the proximal portions of the crural plates. They do not extend anteriorly around the muscle scars. The cardinal process is a short, bifid structure with the two widely separated lobes which appear to rise independently from the medial portions of their respective crural plates.

Discussion.—The dorsal cardinalia bear a strong resemblance to those of *Derbyoides* (Dunbar and Condra, 1932, p. 114, pl. 14, figs. 1-4). However, the crural plates of *Tapajotia* are more recurved posteriorly than those of *Derbyoides*. Also they more closely parallel the hinge line than those of *Derbyoides*, and the lobes of the cardinal process are much more widely separated than in *Derbyoides*. The ventral valves of the two genera are very different. Dunbar and Condra state that *Derbyoides* resembles *Derbyia* except in the structure of the dorsal cardinalia. This means that *Derbyoides* must possess a strong median septum. In *Tapajotia* the median septum is greatly reduced.

It is evident that *Tapajotia* is closely related to *Derbyoides*. It may have evolved from *Derbyoides* by a reduction of the median septum and the dental lamellae and an accentuation and refinement of the features of the dorsal cardinalia, as outlined above. Whether or not it evolved directly from *Derbyoides* is obscure. It may have, but in any case, it is a step beyond *Derbyoides* in evolution along the *Derbyia-Orthotetes* branch of the Orthotetinae subfamily tree, as outlined by Dunbar and Condra (1932, p. 73).

The Tapajós species of this genus has been assigned to two separate genera by previous workers. It was identified as *Streptorhynchus* by Derby (1874, p. 40) when he originally described the fauna, although he suggested that the nature of the dorsal cardinalia might eventually lead to the removal of the Amazon species from *Streptorhynchus*. This, I believe, showed remarkable foresight on Derby's part for his time. The other worker, Katzer (1903, p. 153), assigned his material to the genus *Orthotetes* apparently quite uncritically.

Tapajotia tapajotensis (Derby) Pl. 3, figs. 1-6; Pl. 4, figs. 8,9,11

1874. *Streptorhynchus tapajótensis* Derby, Cornell Univ., Sci. Bull., vol., No. 2, p. 37, pl. 5, figs. 3, 6, 7, 9, 10; pl. 8, fig. 9.
1894. *Streptorhynchus tapajótensis* Derby, Derby, Jour. Geol., vol. 2, p. 492.
1903. *Orthotetes tapajótensis* (Derby), Katzer, Grundzuge de Geologie des Unteren Amazonas Gebietes (des Staates Pará in Brasilien) (= Geologia do Estado do Pará, 1933, p. 153, pl. 6, fig. 5.)
1938. *(non) Derbya tapajótensis* (Derby), Duarte, Serv. Geol. Min. (Brazil), Bol. 84, p. 17, pl. 4, figs. 2-4.

This species is characterized as follows: the poor impression of the muscle scars in both valves; its semicircular shape with the widest portion of the shell being anterior to the transverse mid-line of the shell; the long, relatively narrow palintropes of both valves; the strongly convex deltidium and chilidium; the details of the dorsal cardinalia; the lack of a median septum dividing the musculature in the dorsal valve.

Exterior.—The shell is semicircular in outline, and varies from moderately to mildly resupinate. The long hinge line is a little less than the greatest width of the shell which is just anterior to its transverse mid-line.

The ventral valve is slightly to moderately concave. The palintrope is long and relatively narrow, being about seven or eight times as long as it is high. The delthyrium is about as high as wide, and is covered by a thick deltidium which is convex toward the exterior (posteriorly). The usually moderately distorted beak is, as a rule, about twice as high as are the lateral portions of the palintrope immediately adjacent to the deltidium.

The dorsal valve is regularly and moderately convex. Its palintrope is extremely narrow and elongated. The notothyrium, which is at least six times as wide as it is high, is filled by a solid thickened chilidium which is strongly convex toward the exterior (posterior), its mesial portion extending considerably posterior to the apex of the inconspicious beak.

The ornament consists of strong, radiating costae which increase in number by intercalation. This intercalation produces an alternate ornament which usually has two or three weaker costae between the stronger ones. Sometimes a few moderate to weak growth lines are developed near the anterior margin of the shell.

Interior.—The strong, short, widely diverging teeth of the ventral valve are supported by the greatly reduced dental plates which are represented by mere thickenings or calluses bordering the edges of the deltidium. These dental calluses do not reach the apex of the beak, becoming obsolete at one-half to two-thirds the distance. They are relatively larger in immature specimens, here sometimes extending almost to the beak. A greatly reduced median septum arises from the floor of the valve anterior to the beak. It is usually from 3 to 4 mm. long and 1 mm. or less in height on mature specimens.

The anterior portions of the muscle scars are lightly impressed, and their form is extremely difficult to discern. The posterior portions of the adductors are well impressed on some specimens. They lie on either side of the median septum and arise about the same latitude as does the median septum. They are well impressed anteriorly for about two-thirds the length of the median septum. Anterior to this they are very poorly impressed, and their outline has been seen on only one specimen. Here, the lateral margin of each scar, on either side of the median septum, curves anteromesially to join the lateral margin of the other scar about 2 mm. in front of the end of the median septum. Thus, the overall shape of the adductors is that of a lozenge with a pointed anterior end, a rounded posterior end, and divided by a septum in its posteromesial portion. The shape and distribution of the diductors cannot be determined.

In the dorsal valve the cardinalia are quite complex (fig. 3). The crural plates are nearly parallel with the hinge line. Their internal or anterior surfaces join mesially under the bifid cardinal process to form an arc of about 60 degrees, which is concave toward the anterior. The proximal one-third of the crural plate has its free margin recurved posteriorly to such an extreme degree that it coalesces with the ventro-lateral margin of the chilidium, thus forming a tube, the long axis of which extends laterally and a little anteriorly. The distal portion of the crural plate does not have its free margin as recurved as the proximal portion, and it forms the internal face of a spoon-shaped socket. The extreme distal end of the crural plate is slightly elevated into a sharp ridge, which probably served for attachment of the brachia.

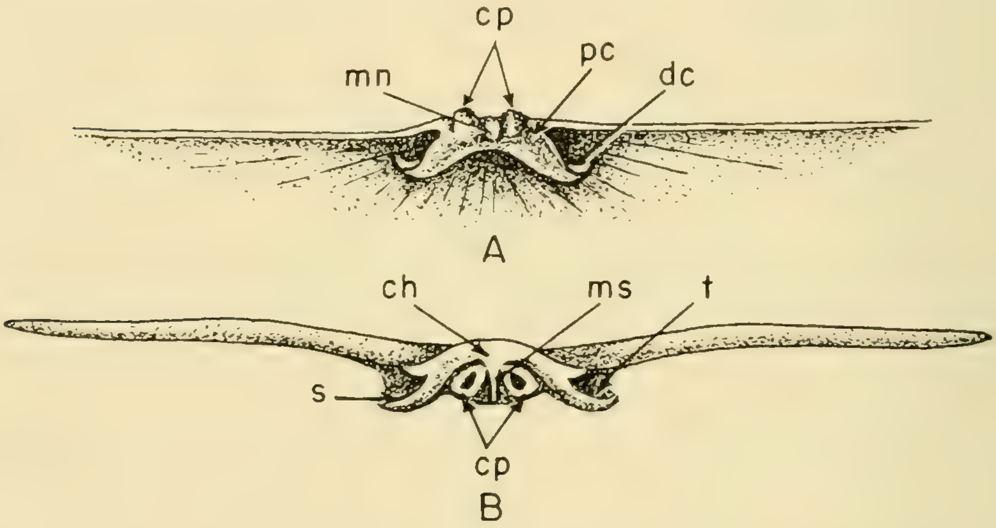


Fig. 3. Dorsal cardinalia of *Tapajótia tapajótensis* (Derby). A. Interior view B. Posterior view. *ch,* chilidium, *cp,* cardinal process, *dc,* distal portion of the crural plates, *mn,* median node, *ms,* median septum, *pc,* proximal portion of the crural plate, *t,* tube formed by the coalescing proximal portion of the crural plate and the lateral edge of the chilidium. Drawing by Elizabeth A. Dalvé.

The cardinal process is a bifid structure lying between the crural plates with its base apparently continuous with them. The lobes of the bifid cardinal process are widely separated, short, strong structures. Between them on the surface of the arc formed by the anterior surfaces of the crural plates is a small, antero-ventrally projecting node. The postero-ventral side of this node is continuous with a plate standing halfway between the two lobes of the cardinal process and joining posteriorly with the internal surface of the chilidium. Thus, there is a median septum between the two lobes of the cardinal process. Unfortunately on most specimens this plate has been partially destroyed and all that remains is a low ridge where the septum once stood. The heavy chilidium overarches the posterior faces of the lobes of the cardinal process, its ventro-lateral margins on either side coalescing with the proximal portions of the crural plates to form the tubes referred to earlier. The posterior faces of the lobes of the cardinal process under the overarching chilidium are each grooved by a gutter which is wider near the end of the cardinal process than it is proximally. It probably served for the attachment of the diductor muscles.

The adductor muscle scars are poorly impressed, their shape and distribution being indeterminable.

Dimensions.—Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm.)
25262	31	36 (rest.)	
25262	20	22	2.5
v.v. 25262	26	32	—
d.v. 25262	10	14	1

Comparison.—Duarte (1938, p.17, pl. 4, figs. 2-4) described and figured a form which he called *Derbyia tapajótensis.* His form appears to be a *Derbyia,* but it is not this species. The cardinalia of his form are entirely different, and a strong median septum is present in his form which is not found in *D. tapajótensis.* Duarte's species is resupinate, and it is apparently upon this feature that he based his assignment of it to *D. tapajótensis.* However, the exterior form of any of the Orthotetinae is a most unreliable character to use for either generic or specific assignment, and since the interiors of the two forms differ so radically, it seems unwise to assign Duarte's material to this species.

Davidson (1857, p. 124, pl. 26, figs. 5,6) described and figured specimens from the Carboniferous of the British Isles which are of the same genus as this species. He grouped these specimens, with many others which are obviously not species of this genus, under the name *Streptorhynchus crenistria* Phillips. These specimens are specifically distinct from *Tapajótia tapajótensis* because they possess a much deeper impression of the muscle scars in both valves. Davidson stated (*ibid.*, p. 126) that he had examined specimens of Hall's *Orthis keokuk* and *O. robusta* and found that they could not be specifically distinguished from British forms of *S. crenistria*. An examination of Hall's plates [1858, pl. 19, fig. 5 *(Orthis keokuk)*, pl. 28, fig. 5 *(Orthis robusta)*] sheds no light upon the validity of this concept. If what he said is valid, and if they are the same as those forms of *S. crenistria* belonging to the genus *Tapajótia*, then *O. keokuk, O. robusta,* and *S. crenistria* will all be a single species under the genus *Tapajótia* but distinct from *T. tapajótensis*.

Stoyanow (1926) reported *Derbyia tapajótensis* from the upper portion of the Pennsylvanian section in the Galiuro Mts. of Arizona (Middle or Upper Pennsylvanian?). He also cited Tschernyschew's identification of Derby's species from the *Schwagerina* limestone (Upper Pennsylvanian) of the Urals.

Number of Specimens Studied.—About 200 specimens consisting mainly of partially broken, dissociated dorsal and ventral valves were studied.

Order **TELOTREMATA** Beecher, 1891

Superfamily **SPIRIFERACEA** Waagen, 1883

Family **ATHYRIDAE** Phillips, 1841

Subfamily **ATHYRINAE** Waagen, 1883

Genus **CLEIOTHYRIDINA** Buckman, 1906

Type species.—*Athyris royssii* Davidson, British Fossil Brachiopoda, vol. 2, part 5, 1857, p. 84, pl .18 figs. 1-11. The Carboniferous limestone (Mississippian) of Great Britain.

1841. *(Non) Cleiothyris* Phillips, Paleozoic Fossils of Cornwall and Devon, p. 55.
1850. *Cleiothyris* Phillips, King, Paleontographical Soc. (The Permian Fossils of England) p. 137, pl. 10, figs. 1-10.
1906. *Cleiothyridina* Buckman, Ann. Mag. Nat. Hist., ser. 7, vol. 18, pp. 323-24.

In proposing this genus Buckman merely named it and designated the type species. He gave no description and neither figured nor listed any supplementary species. He evidently intended King's misinterpretation of *Cleiothyris* Phillips to stand as a generic description for *Cleiothyridina*. Weller (1914, p. 472) stated that this genus differed from *Athyris* in the form of its surface markings; *Cleiothyridina* having the concentric lamellae divided into flat spines by deep incisions; *Athyris* not having these spines. More recent authors, such as Dunbar and Condra (1932, p. 359), and Cooper (in Shimer and Shrock, 1944, p. 333), apparently can find little more than this originally defined difference between the two genera. The interior structures of the two are very similar, and it seems that a restudy should be undertaken to determine whether or not they actually merit distinct generic evaluation.

As abstracted from Dunbar and Condra (1932, p. 359), the internal characters of this genus are as follows: the hinge teeth have short but stout dental lamellae; the dorsal beak has a short hinge plate perforated by a round foramen just inside the beak; this plate is bordered by deep dental sockets, and its front gives rise to the crural plates which arch forward and ventrally; the primary lamellae of the spiralia are recurved abruptly at their origin from the tips of the crural plates. They run dorso-anteriorly and then curve ventrally to give rise to a pair of spiral cones whose apices are directed laterally; the jugum is a complex structure consisting of two limbs rising ventrally to join a saddle-shaped structure, from which a process extends backward almost to the tips of the crural plates and then subdivides into two lamellae which recurve dorsally, closely parallel to the bases of the primary lamellae.

The Tapajós material appears to agree fully with the North American representations of the genus as diagnosed above, except that the jugum is not exhibited, and, therefore, one cannot be sure that it has the same structure as that described above.

The Amazonian specimens have been attributed by previous authors to two separate genera and three North American and European species. These assignments now seem highly questionable. The Tapajós fauna yields what appears to be two new species, one of which has apparently never before been recorded in South American literature. In all probability the species ranges for *Cleiothyridina* are geographically far more circumscribed than older writers supposed.

Cleiothyridina casteri Dresser, n. sp. Pl. 4, figs. 1-7, 10

1874. *Athyris sublamellosa* Hall, Derby, Cornell Univ., Sci. Bull. vol. 1, No. 2, pp. 10-12, pl. 2, figs. 9-12, pl. 3, figs. 15, 21,29; pl. 6, fig. 16; pl. 9, figs. 5, 6.

1894. *Athyris sublamellosa* Hall, Derby, Jour. Geol., vol. 2, p. 419.

1903. *Cleiothyris royssii* Léveille, Katzer, Grundzuge de Geologie des Unteren Amazonas Gebietes (des Staates Pará in Brasilien), p. 164, pl. 5, fig. 5a-c; (= Geologia do Estado do Pará, 1933, p. 154, pl. 5, fig. 5.)

1933. *Cleiothyridina orbicularis* (McChesney), Reed, Ann. Mag. Nat. Hist., vol. 11, (ser.) 10, p. 534.

1938. *Cleiothyridina orbicularis* (McChesney), Duarte, Serv. Geol. Min. (Brazil), Bol. 84, p. 32, pl. 5, figs. 13-16; pl. 6, figs. 9-11.

This species is characterized as follows: the valves are generally about equally convex; some specimens have a broad, anteriorly developed, ventral, mesial sinus and a corresponding dorsal fold; the anterior margin of some specimens is thrown into concentric folds or plications paralleling the lamellae; the dental lamellae reach the floor of the ventral valve; the hinge plate of the dorsal valve is perforated by a large foramen; the fringe of each lamella has about 25 spines per mm., which are often cemented together laterally giving the aspect of larger flattened spines. These spines do not make an angle of over 20 degrees with the surface of the shell.

Exterior.—The shell is circular to transversely oval in outline. The valves are biconvex, the relative degree of inflation of the two valves varying from specimen to specimen. In some specimens the anterior commissure line is broadly uniplicate, *i.e.*, a broad, anteriorly restricted median sinus is developed in the ventral valve along with a corresponding fold in the dorsal valve. Also, many specimens develop concentric folds, largely restricted to the anterior region, and paralleling the lamellae. These folds are usually obscure on the exterior, being represented by the development of a more prominent lamella which has a higher anterior border than the others. This produces the overall external aspect of a grouping of the weaker lamellae between these less common stronger ones, giving an alternate effect to the rugosity. The folds are conspicuous and prominent on the inside of the valve.

The ventral beak is slightly incurved over the wide delthyrial area which surrounds the dorsal beak when the two are articulated, the underside of the ventral beak resting on the umbone of the dorsal valve. The large foramen of the ventral valve occupies the apex of the beak, the umbone of the dorsal valve bounding its underside which is continuous with the open delthyrium of the ventral valve.

The beak of the dorsal valve is less incurved than that of the ventral valve. In life it filled the open delthyrium of the ventral valve. No deltidial or notothyrial plates are evident.

The ornament consists of imbricating lamellae which are more crowded on the sides than middle. Near the middle of the valve the lamellae vary in frequency from 2 to 3 per mm. Each lamella is fringed by many minute spines, some of which are cemented together laterally to give the aspect of large, flattened spines. The minute spines number about 25 per mm., and though generally flattened against the shell surface, they may occasionally make an angle of about 20 degrees with it.

Interior.—The interior of the ventral valve possesses two short, stout teeth which are strongly recurved posteromesially. The teeth are supported by dental plates which descend almost vertically to the floor of the valve and reach somewhat posteriorly into the umbonal region. An indistinct thickening runs transversely across the floor of the umbonal cavity joining their posteroventral ends.

Vague muscle scars are found to lie anterior to this thickening. Their shape is difficult to discern. In one old and large specimen they appear to be six in number, and are of a curious shape and disposition. These comprise, postero-centrally, two small, oval impressions having their posterior portions divided by a wide ridge, thus giving them a somewhat heartlike shape; they are flanked by a pair of circular impressions from which they are separated by a definite ridge; anterior to these four scars, and vaguely separated from them, are two much larger, oval impressions the longer axes of which converge anteriorly toward the longitudinal mid-line of the valve. These last two scars are coalescent and undelimited from each other for about half their total length; however, they are distinctly delimited anteriorly and laterally by a thin, well-defined callus ridge and by differences in the shell texture. They do not extend anteriorly past the transverse mid-line of the valve.

In the dorsal valve there is no cardinal process, as such. However, there is a thickening in the middle of the hinge plate which may have served this function. The foramen of the hinge plate is situated at the beak, and it is about as long antero-posteriorly as the hinge plate is wide in the same direction. A projection of the thickened mesial portion of the hinge plate extends finger-like into the foramen, giving the foramen a heart shape with the apex of the heart pointing toward the beak. Laterally the hinge plate merges with the crural plates which bound the inner margins of the deep dental sockets.

Where the hinge plate and the crural plates unite, they give rise to crural processes which extend ventrally to give rise to the primary lamellae of the spiralia. Postero-laterally from each of the crural processes a trough is developed on the much widened upper (ventral) edge of the crural plate. This trough runs parallel with the crural process, and it is bounded on its postero-lateral side by the postero-lateral portion of the crural plate which is projected above the rest of the widened upper surface of the crural plate into a ridge recurving slightly over the dental socket to the rear.

Originating under the hinge plate on the floor of the valve, just anterior to the beak, is a low, sharp, median ridge. This ridge extends anteriorly about one-third the length of the valve, dividing the muscular impressions into two equal, lightly impressed ovate scars, which extend anteriorly about the same amount.

Dimensions.—Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth(mm.)	
25263	20	22	13	holotype
25264	20	22	14	
25264	17	20	9	
25264	8	8	5	
25264	12	14	8	
25264	16	20	11	
25264	18	22	12	
25264	15	16	9	
25264	13	14	10	

Comparison.—For comparison with the other species with which this species has in the past been identified, see the comparison chart below.

Types.—Holotype, University of Cincinnati Geological Museum, Cat. No. 25263; hypodigm: 195 paratypes, University of Cincinnati Geological Museum, Cat. No. 25264.

Cleiothyridina derbyi Dresser, n. sp. Pl. 5, figs. 1-6

This species is characterized as follows: the outline is longitudinally ovate; the ventral beak is erect, not resting on the umbone of the dorsal valve; small size; relatively narrow, ventral delthyrium;

Cleiothyridina sublamellosa	*Cleiothyridina orbicularis*	*Cleiothyridina royssii*	*Cleiothyridina casteri*	*Cleiothyridina derbyi*
suborbicular to ovate outline.	subcircular to transversely sub-elliptical outline.	circular to transversely oval outline	circular to transversely oval outline.	longitudinally oval, with greatest width at midline.
biconvex, with d.v. more convex than v.v.	biconvex with sometimes d.v. slightly more convex than v.v.	biconvex with d.v. and v.v. of about equal convexity.	biconvex with d.v. and v.v. of about equal convexity.	biconvex with v.v. generally more convex than d.v.
ant. mesial fold and sinus faint, but generally present on old specimens.	very faint anterior mesial fold and sinus on old specimens.	broad mesial fold and sinus of greater of lesser elevation.	broad sinus and fold sometimes developed. Ant. margin sometimes thrown into concentric folds paralleling the growth lamellae.	no anterior mesial sinus or fold present. No concentric folds.
average length and width—19 mm.	max. length and width—16 mm.	max. length and width—68 mm.	max. length and width—22 mm.	largest spec. (v.v.) length—9 mm. width—6 mm.
	short dental lamellae do not reach floor of v.v. hinge plate of d.v. divided almost to apex and is perforated at the beak by a *tiny* foramen.		dental lamellae reach floor of v.v.	dental lamellae reach floor of ventral valve.
			hinge plate of d.v. not divided. Foramen in hinge plate at beak large with mesial thickened portion of hinge plate projecting into it giving a heart-shaped aspect to the foramen with apex of heart toward beak.	dorsal interiors like *C. casteri* except median ridge not so well developed as in *C. casteri*.

the spines sometimes stand at an angle in excess of 30 degrees to the surface of the shell.

Exterior.—The shell is small and longitudinally oval in outline. It is biconvex, either valve sometimes being the more convex.

The ventral beak is erect, projecting considerably posterior to the hinge line and the dorsal beak. The dorsal beak projects into the open, relatively narrow delthyrium of the ventral valve, but the beak of the ventral valve does not rest on the umbone of the dorsal valve. Also, the umbone of the dorsal valve does not serve to delimit the underside of the pedicle opening which is continuous with the open delthyrium of the ventral valve.

The ornament consists of concentric lamellae, the anterior edges of which are broken up into many minute spines. These spines number about 30 per mm., and they are often cemented together laterally to produce the aspect of larger, flattened spines. For this reason they are very difficult to count. They are usually flattened against the surface of the shell, but they may upon occasion make an angle in excess of 30 degrees with it.

Interior.—The strong, short teeth are recurved posteromesially toward the longitudinal mid-line of the valve. They are supported by nearly vertical dental lamellae which reach somewhat posteriorly into the umbonal region. There is no apparent thickening running transversely between their posterior ends, across the floor of the umbonal cavity, as in *Cleiothyridina casteri*.

The muscle scars are generally poorly defined. However, one old and large specimen shows them generally to resemble those of *C. casteri* in number and distribution. They consist of three pairs of impressions lying anterior to the dental lamellae. The posteromesial pair is not separated by a median ridge as in *C. casteri*. It appears as a single scar. It is interpreted to be two undifferentiated scars from analogy with the two posteromesial oval scars of *C. casteri*. Lateral to this undifferentiated scar lie a pair of kidney-shaped impressions corresponding to the lateral, circular impressions of *C. casteri*. They are separated from the undifferentiated posteromesial scar by a definite callus ridge. Anterior to these four posterior scars lies a large, subrounded scar which is separated mesially only at its anterior border. Again, by analogy with *C. casteri*, this scar is made up of two, ovate, coalescent and undelimited scars. This scar is, however, very definitely separated from the two posterolateral kidney-shaped scars by a thickened ridge of callus material.

The dorsal interior is the same as that of *C. casteri*, except that the median ridge is not so well developed as in *C. casteri*.

Dimensions.—Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm).	
25265	3	2.5	1.5	holotype
v.v. 25266	5	4	1.5	
v.v. 25266	9	6	3.5	

Comparison.—This species differs from *C. casteri* in the following characters: it has a longitudinally ovate outline, whereas that of *C. casteri* is circular or transversely ovate; it has a relatively more narrow ventral delthyrium than *C. casteri;* its ventral beak is erect and does not rest on the umbone of the dorsal valve; the spines are more numerous per mm., and they stand at a higher angle to the surface of the shell than in *C. casteri;* there is no apparent callous ridge running across the floor of the umbonal cavity between the posterior ends of the dental lamellae; the muscle scars have a slightly different shape.

Types.—Holotype, University of Cincinnati Geological Museum, Cat. No. 25265. Thirteen paratypes, University of Cincinnati Geological Museum, Cat. No. 25266.

Family **SPIRIFERIDAE** King, 1846

Subfamily **AMBOCOELIINAE** George, 1931

Genus **CRURITHYRIS** George, 1931

Type species.—*Spirifer urei* Fleming, 1828, A History of British Animals, p. 376 (for the specimen figured by Ure, 1793, p. 313 pl. 14, fig. 12). The Avonian (Mississippian) of Strathhaven, Lanarkshire, Great Britain.

Original Description (George, 1931, p. 42).— Hinge line relatively primitive, considerably less than the width of the shell. Ventral umbo markedly incurved. Surface ornament (? smooth to) spinose. Cardinal process sessile, elevated, triangular, tuberculate. Dorsal musculature normally situated, muscle scars elongate.

Discussion.—It would seem that the nature of the cardinal process and the dorsal musculature is enough to establish the validity of this genus, and that the external form, as defined by George, is not diagnostic. The condition of the hinge line being shorter than the width of the shell is not restricted to this genus of the Ambocoeliinae. For instance, Dunbar and Condra (1932, p. 346, pl. 62, figs. 12-14) have shown upon the basis of internal structure and comparison with the types, that *Ambocoelia planoconvexa* (Shumard) from the Pennsylvanian of Nebraska is an undoubted *Ambocoelia*, and yet, its hinge line is shorter than the width of its shell.

The Tapajós material agrees perfectly with the description of this genus, except in a few cases with respect to the width of the hinge line relative to the width of the shell. There are a few ventral valves of which the hinge line is the widest portion of the shell. However, no dorsal valves were found which have the internal characters of *Ambocoelia*. Perhaps these few ventral valves are a distinct species of *Crurithyris*, but until articulated specimens are found, the dorsal valves of which can be studied, the assignment of these valves will have to remain a problem.

Crurithyris granularis Dresser, n. sp. Pl. 5, figs. 12-21

1855. *(Non) Spirifer planoconvexa* Shumard, Geol. Rep. Missouri, p. 202;—Geinitz, 1866, Carbon und Dyas in Nebraska, p. 42, pl. 3, fig. 10-18.

1874. *Spirifer (Martinia) planoconvexa* Shumard, Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2, pp. 19-20, pl. figs. 12, 16, 18; pl. 9, fig. 7.

1894. *Spirifer (Martinia) planoconvexa* Shumard, Derby, Jour. Geol., vol. 2. p. 491.

1903. *Ambocoelia planoconvexa* (Shumard), Katzer, Grundzuge de Geologie des Unteren Amazonas Gebietes (des Staates Pará in Brasilien), p. 164; (= Geologia do Estado do Pará, 1933, p. 154.)

1914. *Ambocoelia planoconvexa* (Shumard), Kozłowski, Annales de Paléontologie; vol. 9, pp. 76-77, pl. 1, fig. 5; pl. 10, figs. 1-14.

1914. *Ambocoelia planoconvexa* (Shumard), Meyer, Neues Jahrb. f. Min., Geol., Paleo., Beil.-Bd. 37, p. 639.

This species is characterized by the following: subcircular to transversely subovate outline; small size; lack of a sinus in either valve; the possession of numerous, thickly set, small spines covering both valves.

Exterior.—The shape of the shell varies from subcircular to suboval. It is biconvex with the ventral valve having much the greater convexity. The beaks of both valves are moderately incurved over their respective areas which are relatively narrow, and which have paradeltidial and paranotothyrial ridges, respectively, bordering their edges. Paradeltidial ridges and paranotothyrial ridges are terms suggested by Dr. Caster for ridges found to border the deltidium and the notothyrium respectively. In the ventral valve their origin is obscure. In the dorsal valve they are formed by the junction of the crural plates with the upturned edges of the palintrope bordering the notothyrium.

The shell texture is granular. On unusually well-preserved specimens this granular texture is seen to be related to the many, tiny spines scattered over the shell surface, the granules of the granular texture representing the spine bases. The spines are small and thickly set in obscurely concentric rows. A few growth lines are usually present. One of these usually circumscribes the shell about its middle. The others are located near the margins. They are generally best developed on the dorsal valves.

Interior.—There are no dental plates or septa within the ventral valve. The recurved teeth are supported by a thickening along the internal edge of the delthyrium.

The mesially situated adductor muscle scars are long, narrow, troughlike depressions extending almost the full length of the valve. They are divided by a faint median ridge. The diductor muscle scars are generally faintly impressed lateral to these adductor scars. On exceptionally well-preserved specimens these are seen to be crescentic depressions originating near the adductor scars under the beak, and reaching their maximum lateral convexity near the middle of the valve. From here they again approach the longitudinal midline of the valve, but they die out before they reach it. They extend anteriorly for about two-thirds the length of the valve. The ventral pedicle muscle scars have their origin in two small holes, one on each side, just lateral to the diductor muscle scars under the thickenings which support the teeth.

In the dorsal valve the dental sockets are deep, conspicuous depressions lying under the dorsal palintrope and bounded on their posterior sides by the palintrope surface. On their anteromedial sides they are bounded by the crural plates which give rise to the crural processes. The crural processes are elongate, rodlike structures diverging slightly as they project anteriorly just above the floor of the valve. No jugum is present. The cardinal process lies between the crural plates at the mid-line. It is a small, ventrally projecting, subconical tubercle.

The muscle scars are vaguely impressed, but they can be determined on exceptionally well-preserved specimens. The posterior adductor scars arise about the same latitude as do the crural processes, and they extend anteriorly about one-third the length of the valve. They are divided by a median ridge throughout their length. Lateral to these and beginning just posteriorly of their anterior ends is another, even less well-defined, groovelike pair of muscle scars, the anterior adductor scars. They extend anteriorly to the transverse mid-line of the shell. No dorsal pedicle muscle scars are visible.

Dimensions.—Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm.)	
25267	3	3	2	holotype
25268	7	7	5	
25268	5	6	4.5	
25268	5	6	4	
25268	4	4	3	
d.v. 25268	6	7.5	2	
d.v. 25268	5	5.5	1	
v.v. 25268	5	5.5	3	
v.v. 25268	7	9	4	

Comparison.—Externally this species greatly resembles *Ambocoelia planoconvexa*. However, it can be differentiated from it if well-preserved interiors are available. These show a small, triangular, ventrally projecting cardinal process contrasted with the posteriorly projecting, bifid cardinal process of *Ambocoelia*. Also, the muscle scars of this species are situated in a normal position, while those of *Ambocoelia* are situated in a medial or anterior position. This then is an example of a remarkable external homeomorphy between *Crurithyris granularis* and *Ambocoelia planoconvexa* (Shumard).

C. granularis is distinguished from other species of the same genus by the lack of a medial sinus in either valve; its generally subcircular outline; and the numerous, thickly set, small spines covering both valves.

This species also somewhat resembles *Phricodothyris perplexa* (McChesney) in its general shape, but it differs from *P. perplexa* in not having double-barreled spines, or as strongly developed concentric ornament. In addition, *P. perplexa* is larger and has a thicker shell. Furthermore, the angle between the crural plates of the dorsal valve is greater than in *C. granularis* and the crural processes of *P. perplexa* are more flattened in a vertical (dorso-ventral) plane than those of *C. granularis.*

Types.—Holotype, University of Cincinnati Geological Museum, Cat. No. 25267. The paratype suite consists of about 660 specimens, mostly dissociated dorsal and ventral valves. They are deposited in the University of Cincinnati Geological Museum, Cat. No. 25268.

Subfamily **RETICULARIINAE** Waagen, 1883

Genus **PHRICODOTHYRIS** George, 1932

(=? **Squamularia** Gemmellaro, 1889)

Type species.—*Phricodothyris lucerna* George, Quart. Jour. Geol. Soc. London, vol. 88, 1932, pp. 516-575, pl. 33, fig. 2; pl. 34, fig. 3; pl. 35, figs. 1-5. The Avonian series, (Mississippian) of Great Britain.

Original Description (George, 1932, pp. 524-525).—

> Brachythyrid, relatively brephomorphic, primitive in shell-form. Spiralia directed more or less laterally; jugum or jugal processes apparently absent. Surface-ornament of biramous barbed spines. Shell structure fibrous impunctate. Internal plates usually absent, but progressive, frequently attaining the primary and sometimes the basilary stage, but never the intermediate stage.

The double-barreled spines are the distinguishing characteristic of this genus. Although George does not say in so many words that this genus is replacing Gemmellaro's genus *Squamularia,* this is in effect what it does, for all reticulariid forms possessing double -barreled spines were previously assigned to it. Gemmellaro's description of *Squamularia* is inadequate by modern standards, and, among other critical omissions, fails to mention double-barrelled spines. The validity of *Phricodothyris* hinges upon a restudy of Gemmellaro's types to determine if they possess double-barreled spines, but since by definition *Phricodothyris* does possess double-barreled spines, the Tapajós material has been tentatively assigned to it.

Phricodothyris perplexa (McChesney) Pl. 6, figs. 1-4, 6

1860. (?) *Spirifer perplexa* McChesney, Descr. New Paleozoic Fossils, p. 43.
1874. *Spirifera (Martinia) perplexa* (McChesney), Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2, pp. 16-18, pl. 3, figs. 27, 39, 40, 45, 50; pl. 8, fig. 13.
1894. *Spirifera (Martinia) perplexa* (McChesney), Derby, Jour. Geol., vol. 2, p. 491.
1903. *Reticularia perplexa* (McChesney), Katzer, Grundzuge de Geologie des Unteren Amazonas Gebietes (des Staates Pará in Brazilien); p. 172, pl. 6, fig. 11a-b; (= Geologia do Estado do Pará, 1933, p. 154, pl. 6, fig. 11).
1903. *Squamularia perplexa* (McChesney), Girty, U. S. Geol. Sur., Prof. Paper 16, p. 392, pl. 6, figs. 8-10 .
1914. *Reticularia lineata* Martin var. *perplexa* (McChesney), Kozłowski, Annales de Paléontologie vol. 9, pp. 73-76, pl. 1, figs. 3, 4; pl. 10, figs. 19-24; *(non)* pl. 10, figs. 25-27.
1914. *Reticularia perplexa* (McChesney), Meyer, Neues Jahrb. f. Min., Geol. Paleo., Beil.—Bd. 37, p. 640, pl. 14, figs. 4a, b.
1929. *Reticularia lineata* Martin var. *perplexa* (McChesney), Steinmann, Geologie von Peru, p. 48, fig. 44.
1930. *Squamularia perplexa* (McChesney), King, Univ. Texas, Bull. 3042, p: 119.
1932. *Squamularia ? perplexa* (McChesney), Dunbar and Condra, Nebraska Geol. Sur., Bull. 5, ser. 2, pp. 313-316, pl. 62, figs. 5-8.
1938. *Squamularia perplexa* (McChesney), Duarte, Serv. Geol. Min., (Brazil), Bol. 84, pp. 31-32, pl. 5, figs. 10-12.

This species is characterized as follows: subcircular shape; strongly developed growth lines; *large* double-barreled spines; posteriorly projecting ventral beak; thickness of the shell; dorso-ventral flattening of the crural processess.

Exterior.—The shell is usually about 1 mm. wider than long, lending a subcircular aspect to it. It is biconvex with the ventral valve being the more convex. The ventral umbone is high and is produced posteriorly further than any other portion of the shell. The dorsal umbone is subdued, ending in a beak which projects a little past the hinge line.

The delthyrium of the ventral valve is about as high as it is wide. It is about one-fourth to one-third as wide as the shell. The notothyrium of the dorsal valve is much less high than the delthyrium of the ventral valves, but it still is about as high as it is wide. It is about one-fifth to one-sixth the width of the shell. Paradeltidial and paranotothyrial ridges are present as in *Crurithyris granularis.* The ventral area is apsacline (the area is inclined ventro-posteriorly), and the dorsal area is orthocline (horizontal), the angle between them being acute.

The ornament of both valves consists of imbricating, concentric lamellae. Each lamella possesses a single concentric row of evenly spaced double-barreled spines. When broken off, they leave a teardrop shaped scar with its apex pointing anteriorly. Between each of these scars, and just anterior to them, is a group of three much smaller scars from which a set of smaller spines arises. In megascopic view the combined visual effect of all of these scars is one of an almost weakly reticulate ornament. This is a characteristic appearance which can never be confused with any other once it has been observed. On well-preserved specimens the large spines are seen to stand at an angle of about 45 degrees to the surface of the shell. The smaller spines stand at an angle of about 20 degrees to the surface.

The shells are thick and heavy. Those of the Tapajós material show a fibrous structure wherever the external layer of the shell has been removed. This structure is probably due to the incomplete silicification of the prismatic calcite below the outer layer of the shell. This is then brought out by the process of etching wherein the acid attacks the calcite and leaves the silica behind as a network, looking not unlike the porous surface of a sponge.

Interior.—Due to the fibrous, spongelike nature of the interiors of almost all of the shells, the muscle scars are not well shown. In those specimens in which they can be vaguely discerned, they are seen to be of about the same shape and distribution as those of *Crurithyris* already described.

No dental lamellae, apertural plates, or median septa occur in the ventral valve of this species. The teeth are supported by a thickened ridge bordering the interior of the delthyrium.

In the dorsal valve no cardinal process has been observed. It is not known if one was ever present. In every case the cardinal area under the beak appears to have been eroded or etched out. Perhaps this rough, rugose appearance is natural, the whole area under the beak serving for the attachment of the diductor muscles. The deep dental sockets are bounded anteromedially by the crural plates, and their posterior portions are covered by the palintrope, just as in *C. granularis*. In the available material all of the crural processes giving rise to the primary lamellae of the spiralia have been broken off close to the cardinal area. All that can be observed about them is that they are dorso-ventrally flattened, at least at their proximal ends.

Dimensions.—Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm.)
25269	15	16	12
25269	9	10	6.5
v.v. 25269	6	6	2.5
v.v. 25269	14	15	6
d.v. 25269	5	6.5	1.5
d.v. 25269	14	15	4

Comparison.—See the discussion under the heading of *Comparison* in the description of *Crurithyris granularis,* n. sp.

Number of Specimens Studied.—About 130 specimens consisting mostly of dissociated dorsal and ventral valves were studied.

Subfamily **SPIRIFERINAE** Schuchert, 1913

Genus **SPIRIFER** Sowerby, 1816

Type species.—*Anomites striatus* Martin, Petref. Derb., 1809, pl. 23. Lower Carboniferous (Mississippian), Great Britain.

As abstracted from Dunbar and Condra (1932, p. 317) this genus is characterized by the following: spiriferoid outline; simple plications on the fold and sinus as well as on the lateral slopes; dorsal palintrope narrower than ventral palintrope; ventral beak larger than the dorsal beak, and it more or less strongly overarches the palintrope; entire surface covered by fine and closely spaced concentric lirae which are crossed by fine radial lirae, making a fine-textured grill; the dental plates are strong vertical septa which diverge more or less; a calluslike thickening under the palintrope commonly more or less envelopes the dental lamellae; dental sockets in the dorsal valve are long and subconical; the crural plates are heavy and bound the inner sides of the sockets, curving inward and upward around the socket. They are united posteriorly under the beak to form a narrow, sloping hinge plate; further forward they are vertical and hang pendant and flangelike, not reaching the floor of the valve; the cardinal process is a low, broad boss marked by deep vertical striations.

Discussion.—The characteristic of having simple plications on the fold and sinus and on the lateral slopes apparently cannot be taken overseriously. Many species are included under the genus *Spirifer* in which one or more of the plications bifurcates, especially on the fold and sinus. It appears that it should be interpreted to mean that most of the plications are simple and do not bifurcate, and those which have arisen by bifurcation usually do not again bifurcate. For instance, in *Spirifer rocky-montani* Marcou, the first pair of plications on either side of the fold invariably join near the beak, *i.e.*, are the result of bifurcation. Also, all of the plications on the fold and in the sinus arise by bifurcation. To carry it one step further, *Neospirifer*, a subgenus of *Spirifer*, is characterized by the fasciculation of the plications, which is produced by their repeated bifurcation. It agrees exactly with *Spirifer* in all other respects. Should it be given separate generic standing merely because the plications bifurcate? The overwhelming mass of evidence from other brachiopod groups, and indeed, from other members of the Spiriferidae, indicates that the internal characters form the best basis for generic classification. It is for this reason that *Neospirifer* is being considered as a subgenus under the genus *Spirifer* in this paper.

Spirifer rocky-montani Marcou Pl. 5, figs. 7-10; Pl. 6, fig. 5

1858. (?) *Spirifer rocky-montani* Marcou, Geology of North America, p. 50, pl 7, figs. 4c, d, e; [*non* figs. 4, 4a, b].
1858. (*Non*) *Spirifer opimus* Hall, Geol. of Iowa, vol. 1, pl. 2, p. 711, pl. 28, figs. 1a, b.
1874. *Spirifer opima* Hall, Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2, p. 15, pl. 1, fig. 4; pl. 2, fig. 7; pl. 4, fig. 12.
1894. *Spirifer rockymontanus* Marcou, Derby, Jour. Geol., vol. 2, p. 491.
1903. *Spirifer rockymontanus* Marcou, Katzer, Grundzuge de Geologie des Unteren Amazonas Gebietes (des Staates Pará in Brasilien), p. 158, pl. 4; fig. 3; (= Geologia do Estado do Pará, 1933, p. 154, pl. 4, fig. 3; pl. 5, fig. 2).
1932. *Spirifer rockymontanus* Marcou, Dunbar and Condra, Nebraska Geol. Sur., Bull. 5, ser. 2, p. 318, pl. 61, figs. 7-9.
1938. *Brachythyris opimus* (Hall), Duarte, Serv. Geol. Min. (Brazil), Bol. 84 ,p. 29, pl. 1, fig. 16.
1938. *Brachythyris rockymontanus* (Marcou), Duarte, Serv. Geol. Min. (Brazil), Bol. 84, p. 30, pl. 6, figs. 5-8.

This species is characterized by the following: presence of six plications in the fold and five in the sinus of the mature specimens; its transversely suboval outline; nine to twelve largely simple plications on each lateral slope; the joining of the first pair of plications on either lateral slope near the beak of the dorsal valve.

Exterior.—The shell is transversely subovate with the widest portion of the shell being a little posterior to the transverse mid-line. The hinge line is only a little shorter than the greatest width, thus making the cardinal extremities slightly obtusely angular. It is biconvex with both valves about equally inflated.

The ventral sinus originates at the moderately incurved beak as a simple furrow. Within one millimeter of the beak a median plication develops in the sinus. Within three millimeters of the beak two more plications, one on either side of the median plication, have bifurcated from the master plication bounding the sinus. There are now three plications in the sinus. The second pair (plications four and five) arise between ten and fifteen millimeters from the beak by bifurcation from the master plications bordering the sinus. This makes a total of five plications in the sinus consisting of two pair and a median one. This is the total number developed within the sinus. Lateral to these there are from ten to twelve plications on each lateral slope, when the master plication bounding one side of the sinus is included in the count. The first plication lateral to the master plication invariably arises from it by bifurcation near the beak.

The dorsal fold arises at the slightly incurved beak as a single plication which bifurcates within one millimeter of the beak into two equal plications. Within three millimeters of the beak, a second pair arises by bifurcation, one from the lateral side of each of the two median plications. Thus, within three millimeters of the beak four plications have arisen. The third pair arises considerably further anteriorly by bifurcation from the lateral sides of the second pair. They usually arise between ten and fifteen millimeters from the beak. There are, then, in the adult, a total of six plications of the fold. Lateral to the fold on each lateral slope there are usually from nine to twelve plications of which the first pair on either lateral slope is invariably joined near the beak, *i.e.*, bifurcates near the beak into two equal plications.

All of the plications of both valves are subangular to rounded, moderately high, and separated by subangular to rounded furrows of width and depth equal to the plications. There is no fasciculation of the plications.

On well-preserved specimens the palintrope is seen to be vertically striated. That of the dorsal valve is considerably narrower than that of the ventral valve, being about half as wide. The ventral palintrope is quite markedly concave. There is a curious groove bordering the delthyrium of the ventral valve and extending a short distance onto the external (posterior) face of the tooth. There is no comparable structure on the dorsal valve.

On well-preserved material the surface is seen to be covered by fine, radial striae distributed over furrow and plication alike.

Interior.—The strong, short teeth are supported by dental plates which reach the floor of the valve only in the umbonal region. From the area immediately below the tooth, where they arise, their free margin extends anteromesially as a sort of platelike projection. They do not meet one another at the mid-line of the valve, but each one does form a surface bounding the interior of the delthyrium and sloping ventro-mesially. Where their fixed edges attach to the margins of the delthyrium, the groove along the external edge of the delthyrium is developed.

The overall aspect of the ventral muscle scars is that of a lozenge-shaped area wherein adductors probably occupied an elongate mesial depression which extends anteriorly for about half the length of the shell. The diductors lie on either side of the adductor impression and are separated from it by the definite ridges which enclose the elongated adductor scar. The diductor scars are about two-thirds as long as the adductor scar. They are considerably wider posteriorly than anteriorly where they are reduced to mere grooves paralleling the adductor groove. The whole of the muscular area is raised above the general internal surface of the valve, and it is bordered by a callus extending anteriorly from the dental plates where they touch the floor of the valve in the umbonal region.

In the dorsal valve the groovelike sockets are covered by a definite, independent plate extending from the beak almost to the anterior margin of the socket, where the tooth of the ventral valve is inserted. This plate lies between the palintrope on the one side and the crural plate on the other. It is depressed between them, but it does not touch the floor of the socket. The crural plate, bounding the medial side of the socket, has its upper margin projected anteroventrally into a blunt toothlike process which lies just anteromesially to the anterior end of the socket. The plate then extends dorsally and a little medially to define the inner walls of the notothyrium. Its free dorsal end gives rise to a laterally flattened crural process which extends anteriorly to give rise to the primary lamellae of the spiralia. It is not known if the crural processess are laterally flattened throughout their length, because in all of the material studied they have been broken off near their proximal ends. Posteromesially the crural plates join to form a shallow, sloping hinge plate from which the cardinal process arises. It is a large, bosslike structure which has its posterior end cut by many grooves for muscle attachment. It resembles that of *Punctospirifer transversa* (McChesney) except that it is not so large, and it is more flattened against the underside of the beak.

The muscle scars are faint and not well defined. They appear to be essentially the same as those of *P. transversa* except that they apparently do not extend up onto the mesial face of the first pair of internal plications. There is an even more tenuous median septum dividing them than in *P. transversa.*

Dimensions.— Univ. of Cincinnati Geol. Mus. Cat. No.

		Length (mm.)	Width (mm.)	Depth (mm.)
	25270	18	23	10 distorted
d.v.	25270	18	25	7
v.v.	25270	19 (rest.)	22	10

Comparison.—This species very much resembles *Spirifer opimus* Hall. According to Dunbar and Condra it differs from *S. opimus* in the following ways: *S. opimus* has four plications on the fold and three in the sinus. *S. rocky-montani* has six plications on the fold and five in the sinus; *S. opimus* has a much higher palintrope on both valves, but especially on the ventral valve, than does *S. rocky-montani.* The plications of *S. opimus* are larger, more angular, and fewer (8-10 on each lateral slope) than in *S. rocky-montani.*

Stoyanow (1926) reported this species from the Galiuro Mts. of Arizona, where its Lower Pennsylvanian position conforms to the general range of the species in the mid-western United States (*e.g.*, Dunbar and Condra, 1939, p. 319).

Number of Specimens Studied.—Twenty-seven specimens which can definitely be assigned to this species were studied. In addition there are about 85 immature forms which cannot be distinguished from the immature forms of *S. (Neospirifer) cameratus* (Morton). The immature and the mature forms consist mostly of dissociated dorsal and ventral valves.

Subgenus **NEOSPIRIFER** Fredericks, 1919

Type species.—Spirifer fascinger Keyserling, Reise nach Petschara-land, 1846, p. 231, pl. 8, fig. 3. Upper Carboniferous of Russia.

This subgenus has the configuration and internal structures of the genus *Spirifer*. It differs from *Spirifer* only in having the plications fasciculated.

There is some question as to whether the species included under the name of *Neospirifer* possesses sufficient structural difference from the genus *Spirifer* to be regarded as representing a separate genus. It is true that there are several species of *Neospirifer*, all possessing the characteristic fasciculation of the plications. However, the importance of this character has been questioned by others such as King (1930, p. 115), who assigned it subgeneric rank. Until evidence demonstrating that this character is of generic significance is brought to light, *Neospirifer* will be tentatively regarded as a subgenus under the genus *Spirifer*.

Spirifer (Neospirifer) cameratus (Morton) Pl. 5, fig. 11; Pl. 7, figs. 7-11

1836. (?) *Spirifer cameratus* Morton, Am. Jour. Sci., vol. 29, p. 150, pl. 2, fig. 3.

1874. *Spirifera camerata* Morton, Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2, pp. 12-15, pl. 1, figs. 1, 3, 6, 9, 14; pl. 2, fig. 15; pl. 4, fig. 5; pl. 5, fig. 11.

1894. *Spirifer cameratus* Morton, Derby, Jour. Geol., vol. 2, p. 491.

1903. *Spirifer cameratus* Morton, Katzer, Grundzuge de Geologie des Unteren Amazonas Gebietes (des Staates Pará in Brasilien), p. 158, pl. 4, fig. 1; (= Geologia do Estado do Pará, 1933, p. 154, pl. 4, fig. 1.)

1914. *Spirifer cameratus* Morton, Kozłowski, Annales de Paléontologie, vol. 9, p. 70, pl. 5, figs. 6-11.

1932. *Neospirifer cameratus* (Morton), Dunbar and Condra, Nebraska Geol. Surv., Bull. 5, ser. 2, pp. 334-336, pl. 39, figs. 4, 6-9b.

This species is characterized as follows: generally weak development of the fasciculation of the plications; 10 plications on the dorsal fold and 12 in the ventral sinus; about 20 plications on each lateral slope; generally suborbicular shape with the width usually a little greater than the length; relatively high delthyrium of the ventral valve when compared with *S. rocky-montani*, the ventral beak being moderately incurved over it.

Exterior.—The shell is suborbicular with the width generally being a little greater than the length. It is biconvex with both valves about equally inflated. The cardinal extremities make an angle with the lateral margins of the shell of about 90 degrees. However, the widest portion of the shell may be either just posterior to the transverse mid-line of the shell or at the hinge line.

The sinus of the ventral valve arises at the apex of the moderately incurved beak. Here it is bounded by two strong plications. About three or four millimeters from the apex of the beak a plication appears in the center of the sinus. Simultaneously, at this same latitude, each of the large plications bounding the sinus gives off a plication from its medial side. This makes a total of five plications in the sinus. As the plications are traced anteriorly, it is seen that each of the first pair of plications to arise from the large bounding plications (those which immediately flank the median plication) bifurcates into two equal plications. This occurs about 17 to 20 mm. from the beak near the transverse mid-line of the valve. At approximately this same latitude each of the large plications bounding the sinus gives off a plication from its inner side. This makes a total of nine plications in the sinus thus far. Still further anteriorly, about 30 mm. from the beak, the second pair of plications to arise from the large bounding plications bifurcates into two equal plications. There are now eleven plications in the sinus. Close to the anterior margin of the shell the median plication of the sinus bifurcates into two equal plications, thus producting the twelfth and last plication in the sinus. In overall aspect the sinus is angular and well defined posteriorly, becoming flattened and ill-defined anteriorly.

The fold of the dorsal valve arises at the apex of the slightly incurved beak. Here it consists of a single, strong plication which bifurcates into two equal plications within three or four millimeters of the apex of the beak. At the same latitude, where it splits into these two equal plications, it simultaneously gives off a lateral plication on each side. Each of these lateral plications is the same strength as the two median ones. Thus, this original, single plication has bifurcated into four equally sized plications within three to four millimeters of the apex of the beak. Within about six to seven millimeters of the beak, each of the two lateralmost plications gives off a plication from its lateral side which is at first smaller than the parent plication, but which becomes equal to it in size anteriorly. This makes a total of six plications on the fold thus far. Further anteriorly, about twelve to fifteen millimeters from the apex of the beak, each of the two original median plications of the fold gives off a plication laterally between itself and the original lateral plication. There are now eight plications on the fold. At approximately the same latitude as this bifurcation occurs each of the two lateralmost plications of the fold, *i.e.*, those formed by the bifurcation of the original lateral plications, gives off a lateral plication. This completes the compliment of plications possessed by the dorsal fold, making a total of ten. In overall aspect the fold is angular and well defined posteriorly becoming flattened and ill-defined anteriorly. The plan of plication is shown diagrammatically in text fig. 4, below.

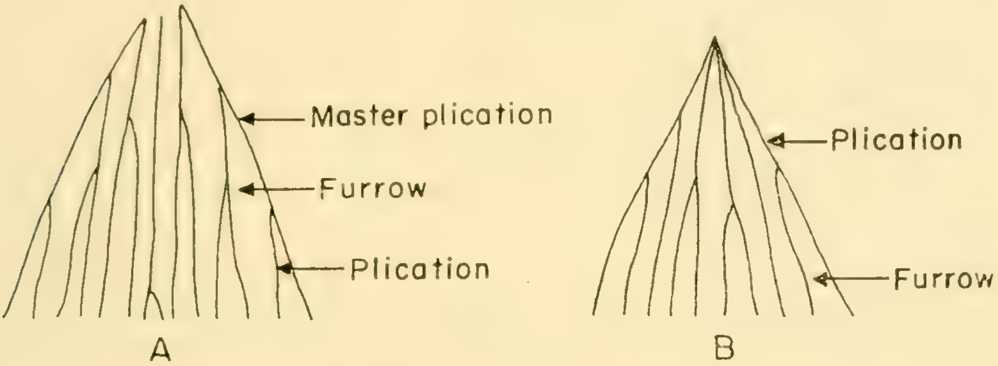


Fig. 4. Pattern of plications on the fold and sinus of *Neospirifer cameratus* (Morton). A. Pattern on the ventral sinus. B. Pattern on the dorsal fold.

The plications of the lateral slopes of both valves are of a non-simple, bifurcating type. There are generally about twenty on each slope. For any given individual the plications on the fold, and sinus, and on the lateral slopes have the same shape. They vary on different individuals from being very low, broad and rounded to moderately high, well defined and subangular. On individuals having the former type the furrows between the plications are reduced to mere lines. This is true on the median portion of the shell only, for as the postero-lateral margins of the shell are approached the furrows increase in width until they are about twice as wide as the plications are there. They widen at the expense of the postero-lateral plications which are reduced to mere low, rounded lines on this portion of the shell. Those individuals with moderately high, subangular plications have furrows of about the same depth and width as the plications throughout the shell. It is in this latter group that the fasciculation of the plications is best shown. In the former type it is at best poorly expressed. The generally poor expression of the fasciculation of the plications is a characteristic of this species.

The palintrope of the ventral valve is high and concave along its longitudinal mid-line. The delthyrium is about as high as it is wide, and it is bounded laterally by grooves extending onto the teeth as in *S. rocky-montani* Marcou.

The palintrope of the dorsal valve is much narrower than that of the ventral valve, and they are perpendicular to each other, the palintrope of the ventral valve being vertical, while that of the dorsal valve is horizontal. The notothyrium of the dorsal valve is from four to six times as wide as it is high.

On well-preserved specimens the surface of the shell can be seen to be covered by fine radial striae distributed over furrow and plication alike.

Interior.—The teeth and the dental plates have the same shape, configuration and relation to the ventral valve as those of *S. rocky-montani.*

The muscle scars have the same general shape as those of *S. rocky-montani,* but they differ in detail. The diductors of this species extend as far anteriorly as the adductors, while in *S. rocky-montani* they extend only about two-thirds as far anteriorly as do the adductors. In addition, the diductors are relatively wider; they extend further into the beak, and they are better impressed and defined than those of *S. rocky-montani.* They extend anteriorly for from one-third to one-half the length of the valve. In general the whole muscular area of this species is broader than that of *S. rocky-montani.* The muscle scars have more of a heartshape with the apex of the heart pointing anteriorly, rather than the lozenge shape of *S. rocky-montani.*

The dorsal valve of this species has exactly the same structures in the same shapes and relations as does *S. rocky-montani.* The only noticeable difference between the two species is that the crural plates of this species are narrower than those of *S. rocky-montani, i.e.,* they do not hang down into the valve as far as those of *S. rocky-montani.*

Dimensions.—Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm.)
25271	38	48	23*
25271	43	65	20** flattened

25271	32	47	18*	
25271	31	43	17*	
25271	35	41	18*	flattened

* Greatest width just posterior to the transverse midline of the shell.
** Greatest width is at the hinge line.

Comparison.—This species differs from other Spiriferidae of the Itaituba fauna in having fasciculated plications, in having more plications on the fold and sinus and on the lateral slopes, and in attaining a larger size. Some specimens much resemble *S. rocky-montani.* However, such specimens can be distinguished from *S. rocky-montani* by the fact that at least some of the plications on the lateral slopes bifurcate. On *S. rocky-montani* only the first pair on either slope immediately adjacent to the dorsal fold bifurcate, and they do so near the beak. The rest of the lateral slope plications are simple.

Neospirifer cameratus is a characteristic Lower Pennsylvanian index in midwestern United States, and has been found by Stoyanow (1926) in this part of his Galiuro Mt. section in Arizona, in association with several elements of the Amazonian Carboniferous fauna.

Number of Specimens Studied.—About 150 specimens consisting mainly of dissociated dorsal and ventral valves were studied.

Spirifer (Neospirifer) cameratus (Morton), variant

Pl. 5, fig. 11; Pl. 8, figs. 1, 4

1874. *Spirifera camerata* Morton, Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2, p. 14, pl. 2, fig. 2.

This variant has all of the characteristics of the species previously described except that the hinge line is extremely drawn out, producing a strongly alate shape. The greatest length is along the hinge line with the result that the angle between the cardinal area and the lateral margin of the shell is about 45 to 50 degrees.

In the Tapajós material there are all gradations between this form and the suborbicular form characteristic of the species.

Dimensions.—Univ. of Cincinati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm.)
25272	32	64	18 holotype
25273	35	74	19 flattened
v.v. 25273	32	76	15 length rest

Family **SPIRIFERINIDAE** Davidson, 1884

Subfamily **SPIRIFERININAE** Schuchert, 1929

Genus **PUNCTOSPIRIFER** North, 1920

Type species.—Punctospirifer scabricosta North, Quart. Jour. Geol. Soc. London, vol. 76, 1920, p. 213 [= *Spiriferina laminosa* (McCoy), Garwood, 1912]. Ashfell sandstone (Carboniferous) Great Britain.

As abstracted from North's original description (1920, pp. 212-213), the genus possesses the following characters: shell spiriferoid, about twice as wide as long with the greatest width at or near the hinge line; cardinal extremities slightly rounded or subangular; area moderately high and concave; biconvex with a well-developed, distinct mesial fold and sinus; lateral slopes evenly convex and ornamented by round plications separated by equally wide rounded furrows; surface of both valves crossed by regularly disposed imbricating lamellae, shell structure fibrous and strongly punctate; dental plates slightly divergent; ventral median septum well developed, about two-thirds as high as the ventral palintrope and about half as long as the shell; no marked apical callosity; a low median crest bisects the muscle area of the dorsal valve; spiral coils large with the apices directed laterally to a point a little anterior to the cardinal extremities; jugum is a slender V-shaped process with its apex directed postero-ventrally.

Discussion.—According to Dunbar and Condra (1932, p. 351) *Punctospirifer* differs from *Spiriferina* as follows: fold and sinus are wider than the lateral plications and are flattened in *Punctospirifer;* the angular fold and sinus are not sharply differentiated from the costae in *Spiriferina.* The cardinal area is clearly separated from the lateral slopes by an abrupt angle in the shell in *Punctospirifer.* It is not separated from the lateral slopes by a sharp angle in the shell in *Spiriferina.* The surface is closely lamellose at all stages of growth in *Punctospirifer.* The surface is closely lamellose only at the anterior margin in *Spiriferina. Punctospirifer* possesses a V-shaped jugum. *Spiriferina* possesses a simple, transverse jugum.

The Tapajós material agrees in every respect with the genus *Punctospirifer.*

Punctospirifer transversa (McChesney) Pl. 7, figs. 1-6

1859. (?) *Spirifer transversa* McChesney, New Paleozoic Fossils, p. 42.

1874. *Spiriferina transversa* (McChesney), Derby, Cornell Univ., Sci. Bull., vol. 1, No. 2, pp. 21-23, pl. 2, figs. 4-6, 13; pl. 3. figs. 12-24, 17; pl. 5, fig. 4.

1903. *Spiriferina transversa* (McChesney), Katzer, Grundzuge de Geologie des Unteren Amazonas Gebietes (des Staates Pará in Brazilien), p. 158, pl. 4, fig. 2a-c; (= Geologia do Estado do Pará, 1933, p. 154, pl. 4, fig. 2; pl. 5, fig. 3)

1914. *Spiriferina transversa* (McChesney), Weller, Geol. Surv. of Illinois, Mon. 1. pp. 297-299, pl. 35, fibs. 41-49.

This species is characterized by the following: a single slight groove and slight plication in the dorsal mesial fold and ventral mesial sinus respectively; eight to twelve plications on each lateral slope; width of the shell is about twice its length; biconvex nature of the shell with the ventral valve slightly more inflated than the dorsal; heavy, solid, posteriorly grooved cardinal process and extension of the dorsal muscle scars onto the mesial face of the first pair of internal plications; and the presence of the thin, dorsal, mesial septum dividing the muscle scars.

Exterior.—The shell is typically spiriferoid, about twice as wide as long with the greatest width at or near the hinge line. The cardinal margins are acutely angular in mature specimens and often rounded in immature specimens with the greatest width of the shell in these being just anterior to the hinge line. The shell is biconvex, the ventral valve often being slightly more inflated than the dorsal.

The umbone of the ventral valve is only slightly inflated, and the beak is only slightly incurved over a delthyrium which is about as wide as it is high. The umbone of the dorsal valve is even flatter than that of the ventral valve, and the beak is only slightly incurved over a notothyrium which is about one-fourth as high as it is wide. The palintropes of the two valves lie at nearly a right angle to each other, that of the ventral valve being vertical and that of the dorsal valve being horizontal.

The dorsal fold and the ventral mesial sinus are well developed. They are about as wide as two or three plications and their included furrows. On the dorsal fold a slight median groove often develops just anterior to the beak. There is a corresponding slight median fold in the sinus of the ventral valve. On mature specimens there are from eight to twelve simple plications on each lateral slope. Usually the first three or four of these take their origin from the beak. The rest of them originate from the cardinal margin which is a sharp angle separating the lateral slopes from the palintrope area.

The ornament other than the plications consists of regularly spaced inbricating growth lamellae which number from four to five per millimeter near the transverse midline of the valve. The shell structure is fibrous and coarsely punctate, the punctae tending to be arranged more or less concentrically parallel to the growth lamellae.

Interior.—The strong, diverging teeth of the ventral valve are supported by dental plates whose medial sides are slightly convex. Their anterior edges are concave, and they diverge slightly anteriorly. They extend anteriorly for about one-fourth to one-fifth the length of the valve, and between them lies the thin median septum, the concave anterior margin of which rises to an apex just anterior to the space between the teeth. It extends anteriorly for about half the length of the valve. The muscle scars could not be delimited on the available material.

In the dorsal valve the heavy crural plates are united mesially to form a hinge plate from which the large rounded cardinal process arises. The cardinal process fills the whole mesial portion of this plate. Its posterior end is divided by deep grooves into sometimes as many as nine, subequal, laterally flattened projections. The grooving of the posterior end of the cardinal process probably facilitated muscle attachment. The groove-shaped dental sockets lie lateral to the heavy crural plates which are projected into a blunt tooth just anteromesially of the anterior termination of the socket floor. No portion of the groove-shaped sockets is covered by a plate or by the palintrope.

The hinge plate formed by the fusion of the mesial edges of the crural plates is supported underneath by the posteriorly joined ends of the first pair of internal plications. This first pair of internal plications is stronger and is better developed than any other internal plications of the shell; these plicae are the internal reflections of the first pair of furrows which bound the medial fold. A thin, tenuous median septum originates where the posterior ends of this first pair of internal plications come together. It extends anterior for about two-thirds the length of the valve, dividing the muscle scars into equal lateral halves.

These halves extend onto the median faces of this strongly developed first pair of internal plications, causing their ventral edges to be flattened laterally and extended ventrally into a slight ridge which is higher than the rest of the plication. This ridge extends anteriorly along the plication for about half the length of the shell. The muscle scars between the plications on either side of the tenuous median septum are poorly impressed.

Dimensions.—Univ. of Cincinnati Geol. Mus. Cat. No.

	Length (mm.)	Width (mm.)	Depth (mm.)
25274	15	28	17
25274	15	22	11
25274	19 (rest.)	35	15
d.v. 25274	15	26	6
v.v. 25274	5.5	10	3

Comparison.—This form differs from *Punctospirifer kentuckyensis* (Shumard), which it superfically somewhat resembles, in the following characters: *P. kentuckyensis* has five to six plications on each lateral slope. This species has eight to twelve plications on each lateral slope. In *P. kentuckyensis* the cardinal process is a minute, rounded nub. In this species it is a large, bosslike, posteriorly grooved structure. *P. kentuckyensis* has the hinge plate supported by the median septum. This species has it supported by the posteriorly joined ends of the first pair of internal plications (the internal reflections of the first pair of furrows on either side of the dorsal fold).

Punctospirifer transversa ranges low in the Carboniferous section of the midcontinental United States. Dunbar and Condra (1932), e.g., gives the range as Chesterian and Morrowian (Upper Mississippian and Lower Pennsylvanian).

Number of Specimens Studied.—About 75 specimens consisting in large part, of dissociated dorsal and ventral valves were studied.

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PLATES

PLATE 1 (6)

Explanation of Plate 1 (6)

Figure		Page
1-4,6,7.	**Rhipidomella penniana** Derby	21

1. Ventral interior showing the large flabelliform muscle scars. × 2. Univ. of Cincinnati Geol. Mus., No. 25258.
2. Dorsal interior showing the high notothyrial platform with its trilobed posterior face and the deep muscle scars. × 2. Univ. of Cincinnati Geol. Mus., No. 25258.
3. Ventral interior showing the muscle scars and the punctae. × 2. Univ. of Cincinnati Geol. Mus., No. 25258.
4. Laterial view showing a definite interarea between the valves. × 2. Univ. of Cincinnati Geol. Mus., No. 25258.
6. Dorsal exterior. × 2. Univ. of Cincinnati Geol. Mus., No. 25258.
7. Posterior view of a dorsal valve showing the trilobed character of the posterior face of the cardinal process and the prominent crural plates. × 2. Univ. of Cincinnati Geol. Mus., No. 25258.

5. **Streptorhynchus hallianus** Derby 27

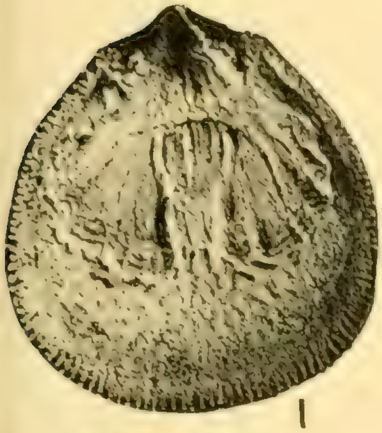
Ventral exterior showing the plicated anterior margin of shell. × 2. Univ. of Cincinnati Geol. Mus., No. 25260.

8-11,13. **Orthotichia morganiana** (Derby) 24

8. Posterior view of a slightly distorted specimen. × 2. Univ. of Cincinnati Geol. Mus., No. 25259.
9. Ventral interior showing the short median septum and the dental plates. × 2. Univ. of Cincinnati Geol. Mus., No. 25259.
10. Posterior view of a dorsal valve showing the small cardinal process and the prominent crural processes. × 2. Univ. of Cincinnati Geol. Mus., No. 25259.
11. Dorsal interior showing the diverging crural plates, the small cardinal process, and the median ridge. × 2. Univ. of Cincinnati Geol. Mus., No. 25259.
13. Ventral interior showing the median septum, dental lamellae and teeth. × 2. Univ. of Cincinnati Geol. Mus., No. 25259.

12. **Derbyia correanus** (Derby) 30

Posterior view showing the cardinal process with the grooves for muscle attachment and the crural plates. × 2. Univ. of Cincinnati Geol. Mus., No. 25261.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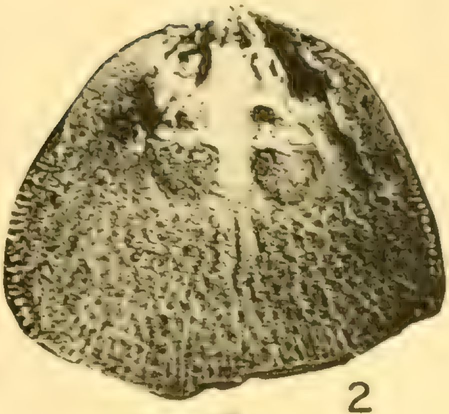
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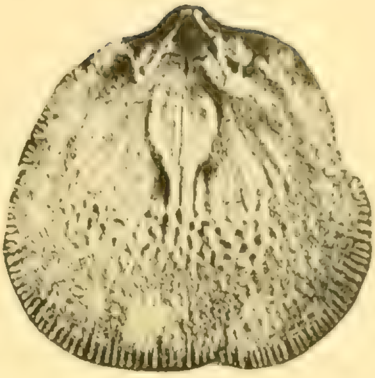
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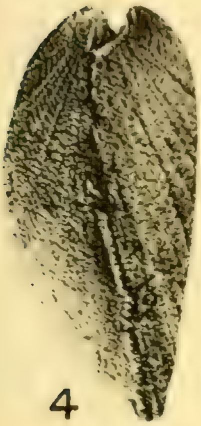
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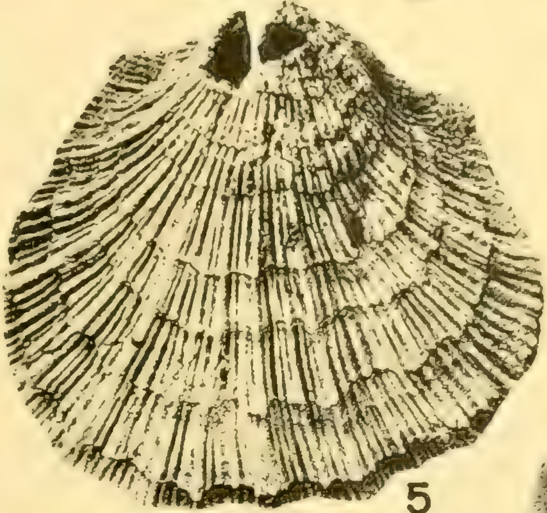
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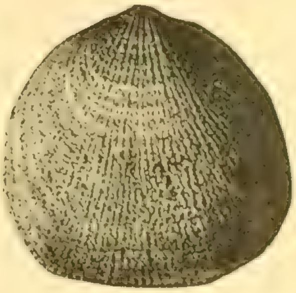
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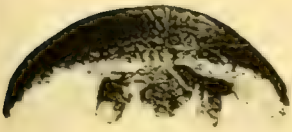
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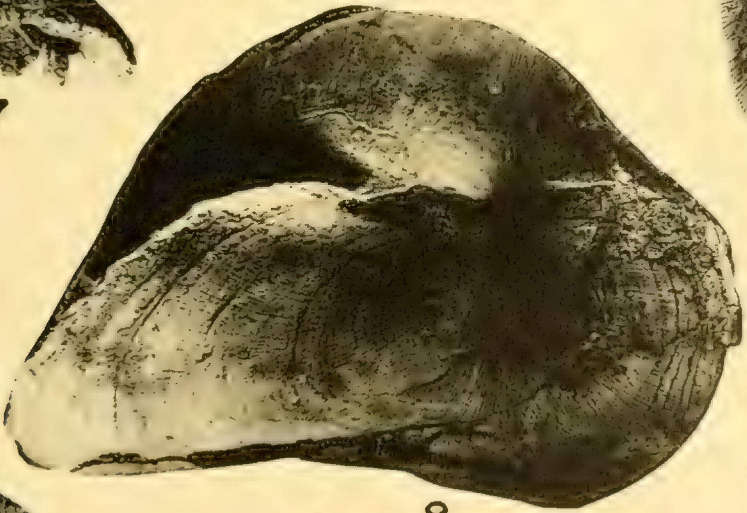
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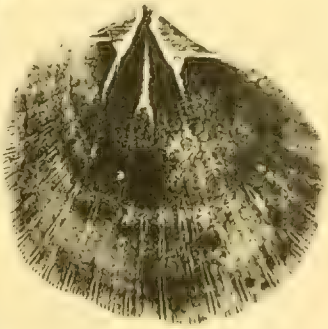
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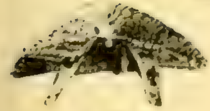
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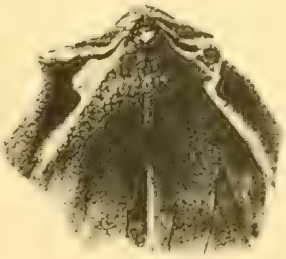
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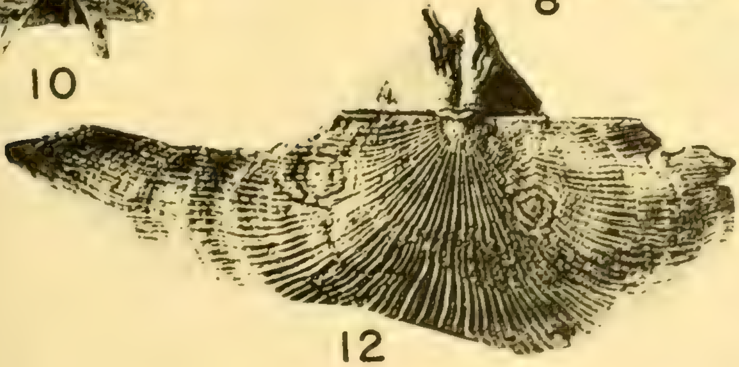
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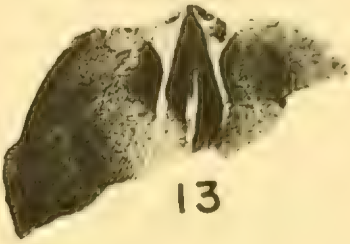
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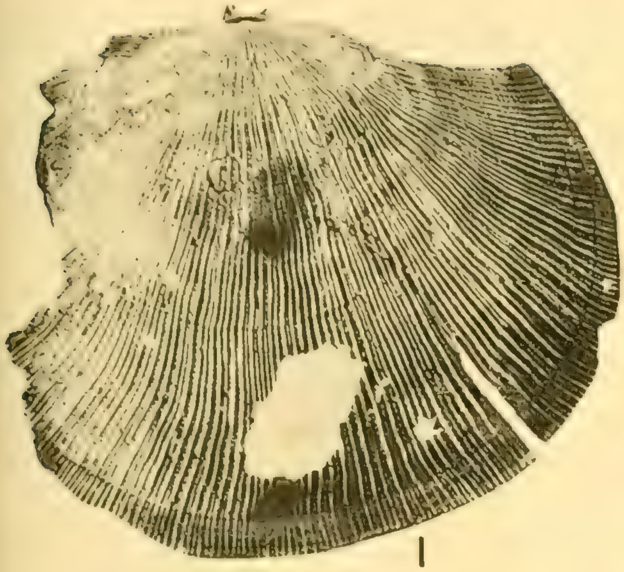
PLATE 2 (7)

Explanation of Plate 2 (7)

Figure Page

1-6. **Derbyia correanus** (Derby) 30

1. Dorsal exterior. × 1½. Univ. of Cincinnati Geol. Mus., No. 25231.
2. Ventral interior showing the median septum, teeth, palintrope, and deltidium. × 1½. Univ. of Cincinnati Geol. Mus., No. 25261.
3. Dorsal interior showing the weak ridge dividing the scars and the cardinal process. ×2. Univ.of Cincinnati Geol. Mus., No. 25261.
4. Dorsal interior showing the dental socket and the silicified material filling the valve. × 1½. Univ. of Cincinnati Geol. Mus., No. 25261.
5. Dorsal exterior showing the alternate ornament. × 1½. Univ. of Cincinnati Geol. Mus., No. 25261.
6. Ventral interior showing the median septum, interior of deltidium, and the dental calluses. ×1½. Univ. of Cincinnati Geol. Mus., No. 25261.



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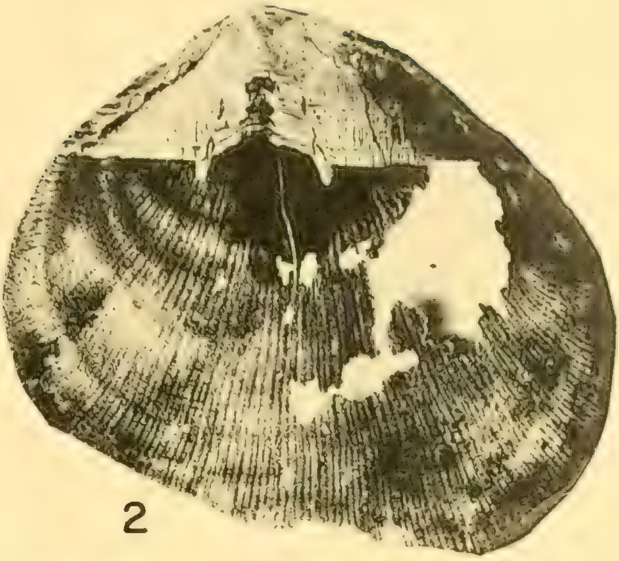

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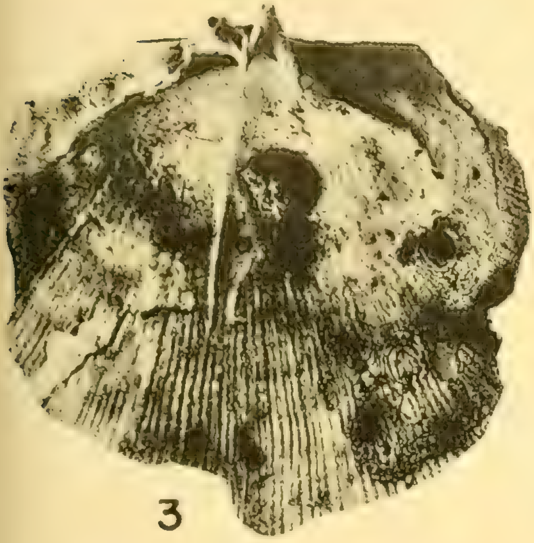

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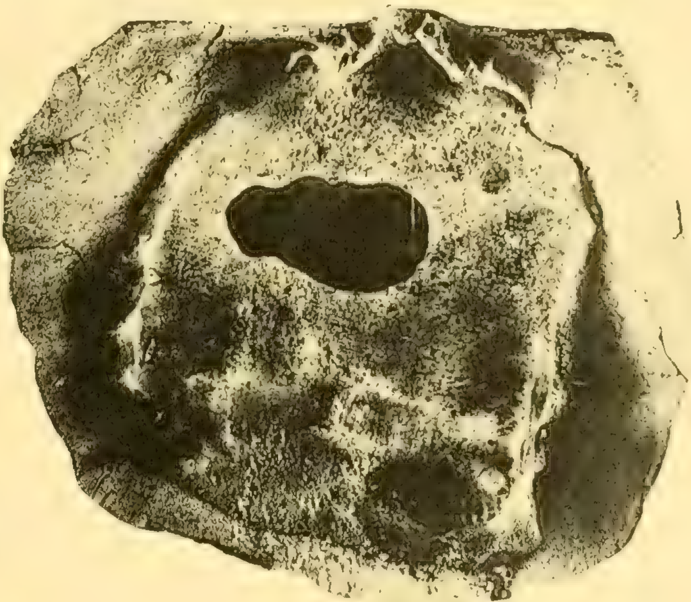

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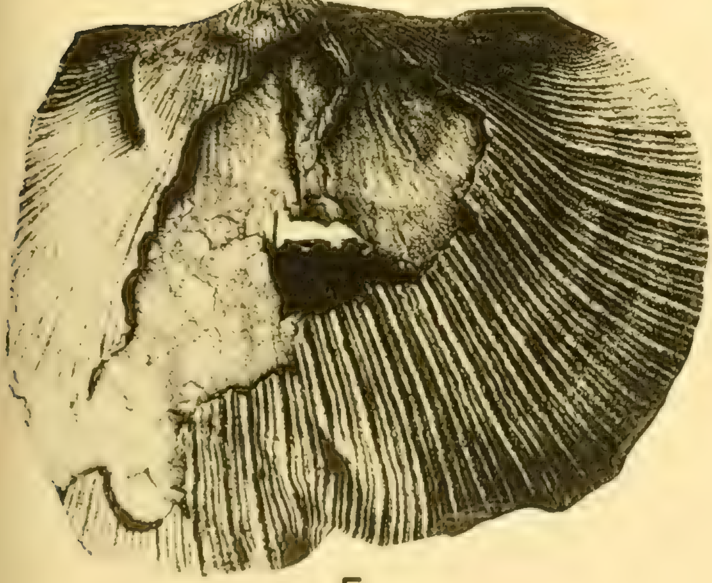

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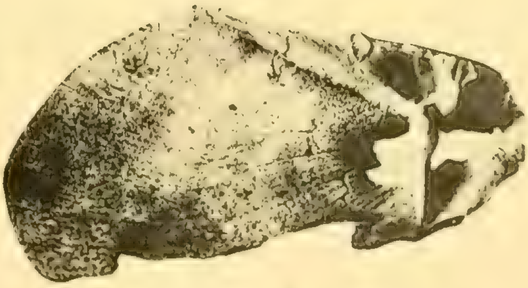

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PLATE 3 (8)

Explanation of Plate 3 (8)

Figure		Page
1-6.	**Tapajotia tapajotensis** (Derby)	34

1. Dorsal exterior showing the over-arching chilidium and the ornament. × 2. Univ. of Cincinnati Geol. Mus., No. 25262.

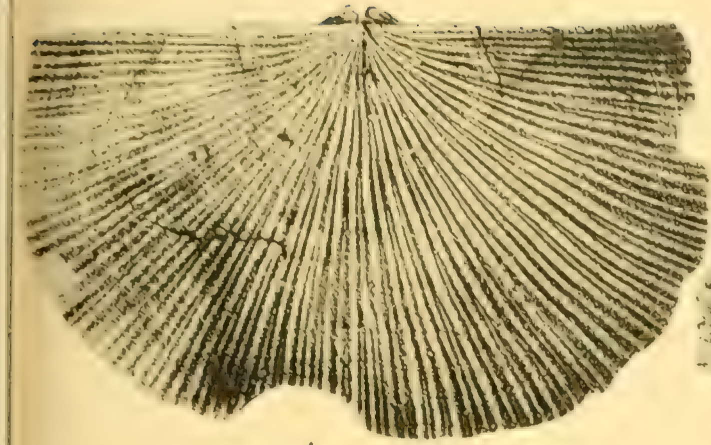
2. Posterior view showing the deltidium and the chilidium. × 2. Univ. of Cincinnati Geol. Mus., No. 25262.

3. Dorsal interior showing the bifid cardinal process, the median node, and the dental sockets. ×2. Univ. of Cincinnati Geol. Mus., No. 25262.

4. Ventral interior showing the very reduced median septum and a portion of the muscle scars. × 2. Univ. of Cincinnati Geol. Mus., No. 25262.

5. Ventral exterior showing the slightly twisted beak and the ornament. × 2. Univ. of Cincinnati Geol. Mus., No. 25262.

6. Dorsal interior. × 2. Univ. of Cincinnati Geol. Mus., No. 25262.



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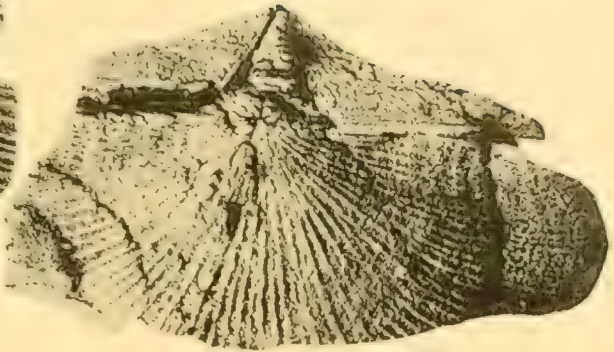

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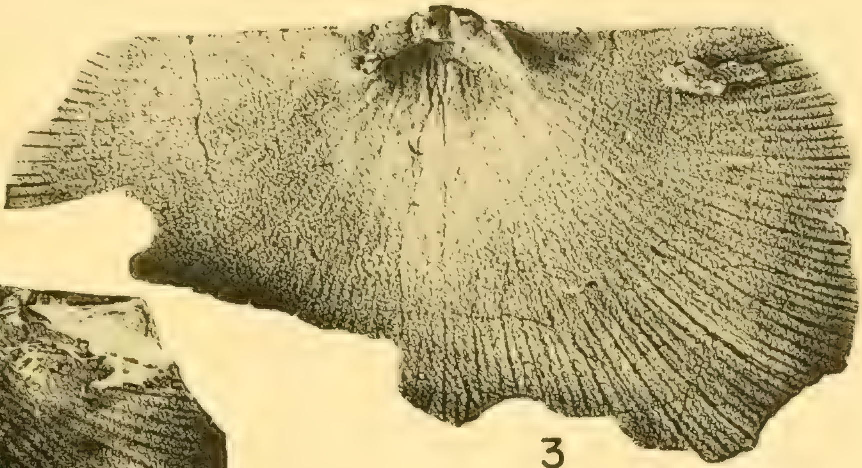

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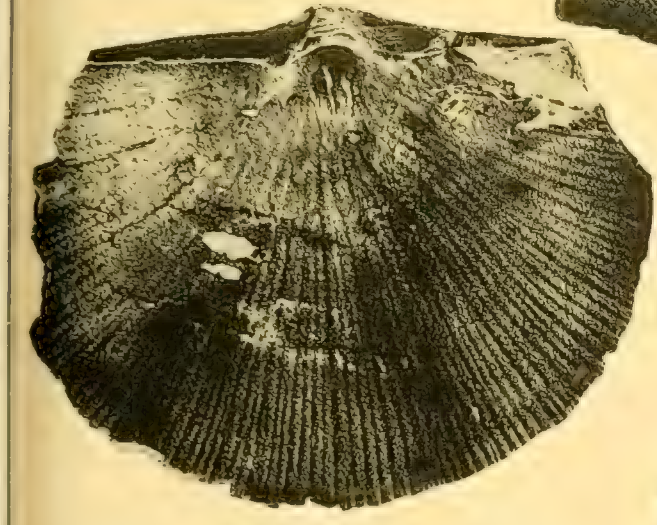

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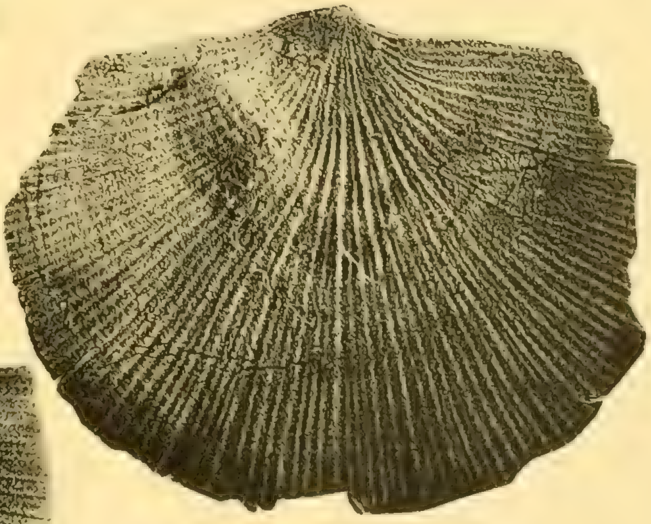

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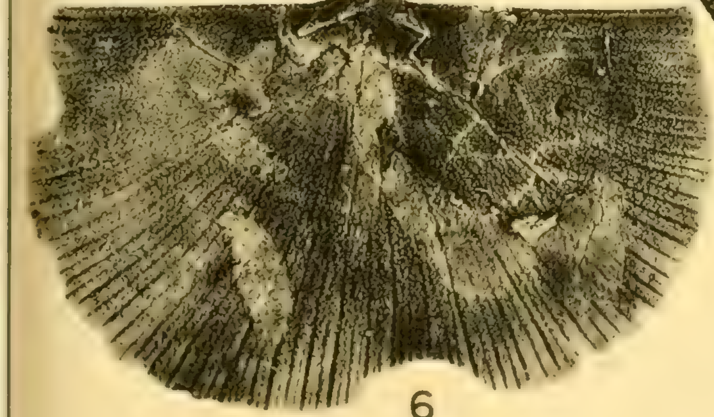

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PLATE 4 (9)

Explanation of Plate 4 (9)

Figure		Page
1-7,10.	**Cleiothyridina casteri** Dresser, n. sp.	39

1. Ventral exterior showing the growth lamellae and the spines. × 4. Univ. of Cincinnati Geol. Mus., No. 25264. Paratype.

2. Lateral view showing the imbricating growth lamellae, the recurved ventral beak, and the spines. ×4. Univ. of Cincinnati Geol. Mus., No. 25263. Holotype.

3. Ventral view showing how the spines are often cemented to each other laterally. × 4. Univ. of Cincinnati Geol. Mus., No. 25263. Holotype.

4. Ventral interior showing the anteriorly restricted concentric plications and the posteriorly recurved teeth. × 4. Univ. of Cincinnati Geol. Mus., No. 25264. Paratype.

5. Ventral interior showing the posteriorly recurved teeth. × 4. Univ. of Cincinnati Geol. Mus., No. 25264. Paratype.

6. Dorsal interior showing the relatively large foramen in the hinge plate, the antero-laterally projecting grooves on the top edges of the crural plates, the dental sockets, and the median ridge. ×4. Univ. of Cincinnati Geol. Mus., No. 25264. Paratype.

7. Dorsal interior. × 4. Univ. of Cincinnati Geol. Mus., No. 25264. Paratype.

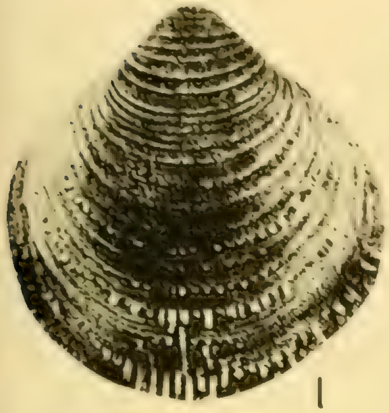
10. Dorsal interior. × 4. Univ. of Cincinnati Geol. Mus., No. 25264. Paratype.

8,9,11.	**Tapajotia tapajotensis** (Derby)	34

8. Dorsal interior showing the bilobed cardinal process, the median node, and the tubes formed by the recurved proximal portions of the crural plates. × 4. Univ. of Cincinnati Geol. Mus., No. 25262.

9. Dorsal interior showing the tubes formed by the recurved proximal portions of the crural plates. × 4. Univ. of Cincinnati Geol. Mus., No. 25262.

11. Posterior view of the dorsal valve showing the partially broken, over-arching chilidium, the median septum between the lobes of the cardinal process, and the grooves for muscle attachment on the posterior faces of the lobes of the cardinal process. × 4. Univ. of Cincinnati Geol. Mus., No. 25262.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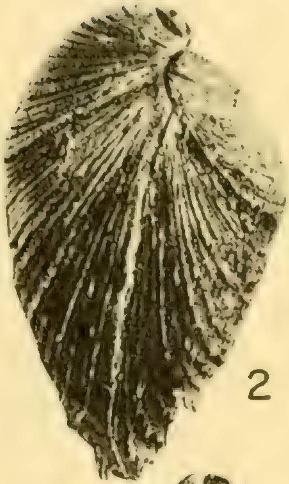
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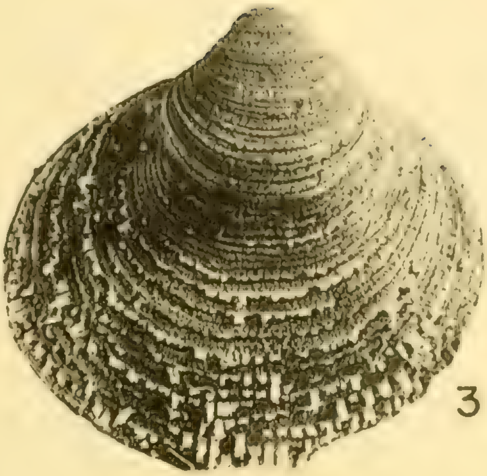
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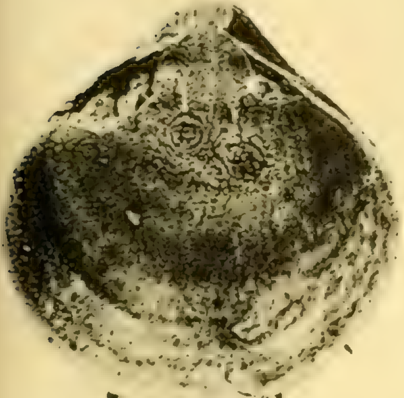
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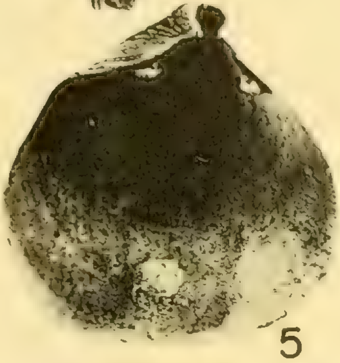
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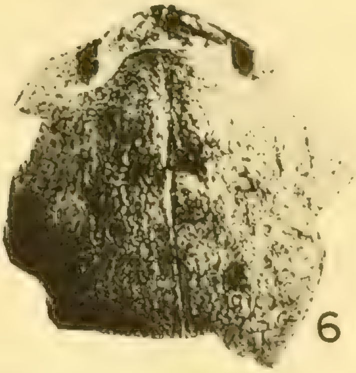
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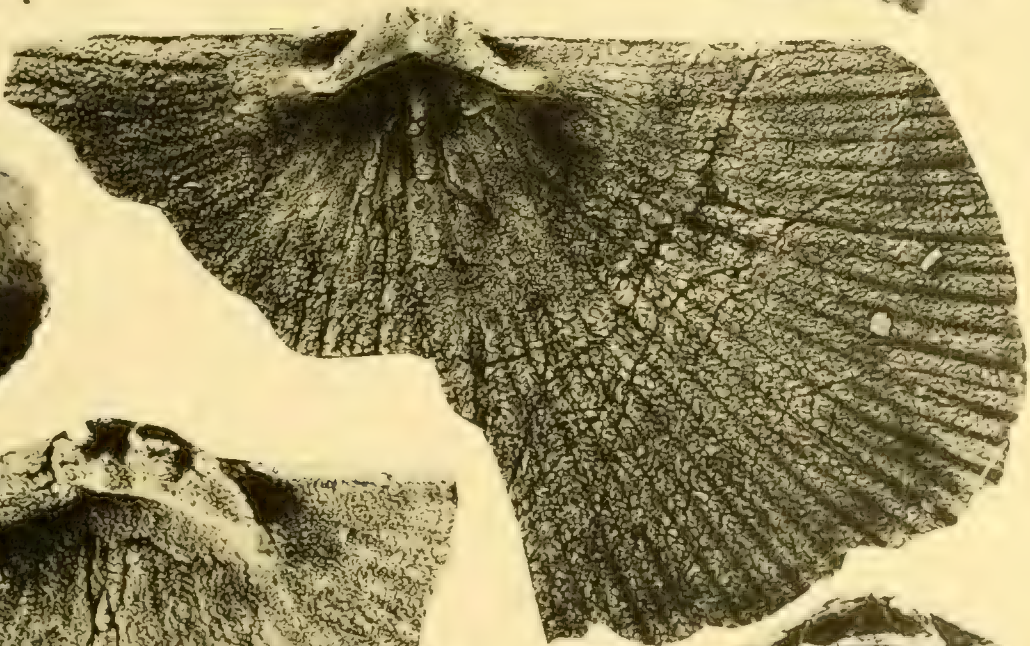
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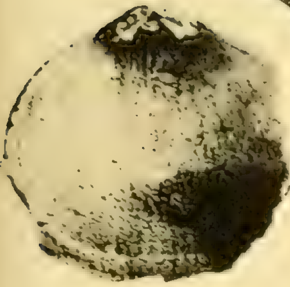
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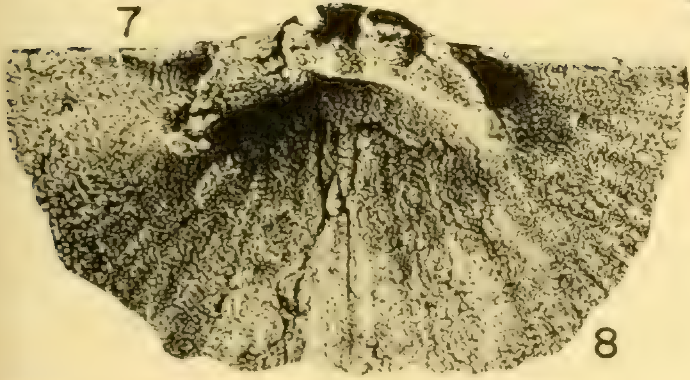
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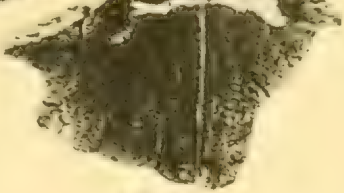
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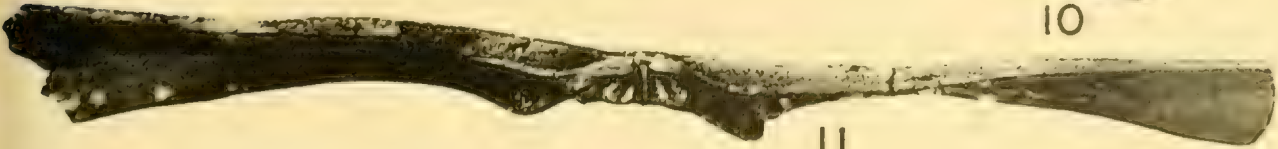
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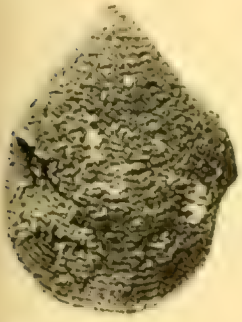
PLATE 5 (10)

Explanation of Plate 5 (10)

Figure		Page
1-6.	**Cleiothyridina derbyi** Dresser, n. sp.	42
	1. Ventral exterior showing the elongate shape and the growth lamellae. × 4. Univ. of Cincinnati Geol. Mus., No. 25266. Paratype.	
	2. Ventral interior showing the erect beak, the posteriorly recurved teeth, and suggestions of the muscle scars. × 4. Univ. of Cincinnati Geol. Mus., No. 25266. Paratype.	
	3. Dorsal exterior showing the elongate shape, the imbricating growth lamellae, and the spines. ×4. Univ. of Cincinnati Geol. Mus., No. 25266. Paratype.	
	4. Dorsal interior showing the relatively large foramen in the hinge plate and the antero-laterally directed grooves on the top edges of the crural plates. × 4. Univ. of Cincinnati Geol. Mus., No. 25266. Paratype.	
	5. Dorsal view of an articulated specimen showing the erect ventral beak and the spines. × 4. Univ. of Cincinnati Geol. Mus., No. 25265. Holotype.	
	6. Dorsal view of an articulated specimen showing the elongate shape and the growth lamellae. ×4. Univ. of Cincinnati Geol. Mus., No. 25266. Paratype.	
7-10.	**Spirifer rocky-montani** Marcou	53
	7. Dorsal interior showing the tenuous median septum, the posteriorly grooved cardinal process, vague muscle scar impressions, and the crural plates. ×2. Univ. of Cincinnati Geol. Mus., No. 25270	
	8. Ventral interior showing the muscle scars, the dental lamellae, and the teeth. ×2. Univ. of Cincinnati Geol. Mus., No. 25270.	
	9. Dorsal exterior showing the six plications on the fold, and the bifurcation, near the beak, of the first pair of plications on either side of the fold. ×2. Univ. of Cincinnati Geol. Mus., No. 25270.	
	10. Ventral exterior showing four of the five plications in the sinus. × 2. Univ. of Cincinnati Geol. Mus., No. 25270.	
11.	**Spirifer (Neospirifer) cameratus** (Morton), variant	61
	Dorsal exterior showing the acute angle between the cardinal area and the lateral margins; and the vague fasciculation of the plications. × 2. Univ. of Cincinnati Geol. Mus., No. 25273. Paratype.	
12-21.	**Crurithyris granularis** Dresser, n. sp.	46
	12. Dorsal exterior showing the general shape, and the few growth lamellae generally present. ×4 . Univ. of Cincinnati Geol. Mus., No. 25268. Paratype.	
	13. Ventral exterior showing the general shape. × 4. Univ. of Cincinnati Geol. Mus., No. 25268. Paratype.	
	14. Ventral interior showing the paradeltidial ridges on either side of the delthyrium. × 4. Univ. of Cincinnati Geol. Mus., No. 25268. Paratype.	
	15. Lateral view showing the relative convexity of the valves. ×4. Univ. of Cincinnati Geol. Mus., No. 25268. Paratype.	
	16. Posterior view. × 4. Univ. of Cincinnati Geol. Mus., No. 25268. Paratype.	
	17. Dorsal view of an articulated specimen. × 4. Univ. of Cincinnati Geol. Mus., No. 25268. Paratype.	
	18. Dorsal interior showing the paranotothyrial ridges on either side of the notothyrium. × 4. Univ. of Cincinnati Geol. Mus., No. 25268. Paratype.	
	19. Dorsal interior showing the small, ventrally projecting cardinal process, the crural process and crural plates. × 4. Univ. of Cincinnati Geol. Mus., No. 25268. Paratype.	
	20. Ventral interior vaguely showing the muscle scars. × 4. Univ. of Cincinnati Geol. Mus., No. 25268. Paratype.	
	21. Dorsal interior showing the cardinal process, the crural plates, and the crural processes. ×4. Univ. of Cincinnati Geol. Mus., No. 25268. Paratype.	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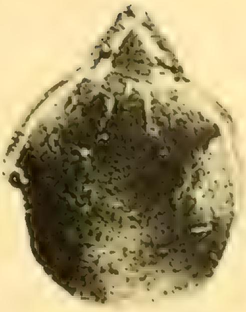
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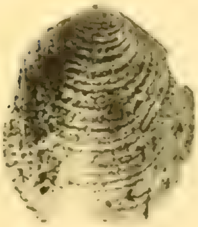
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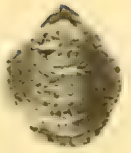
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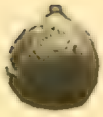
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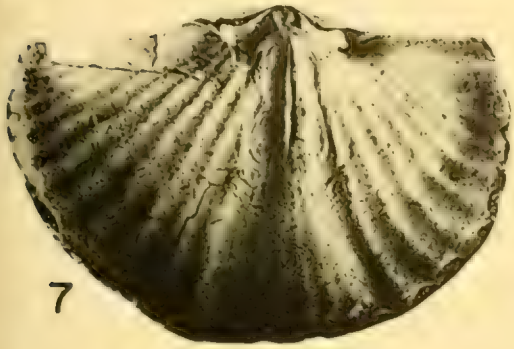
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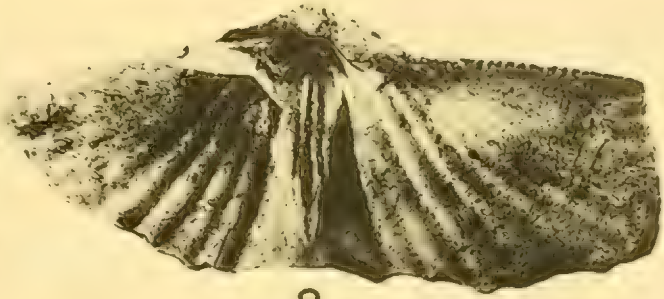
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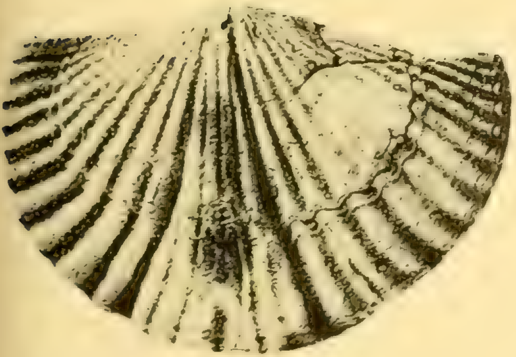
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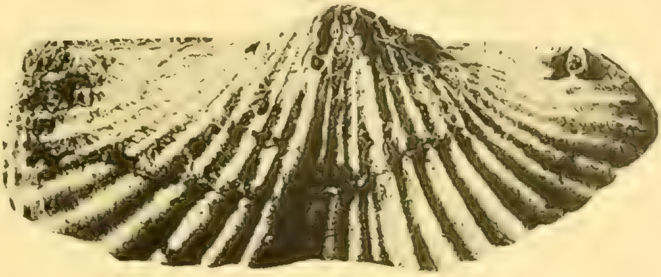
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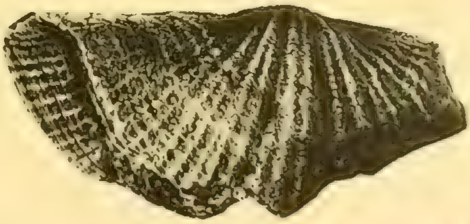
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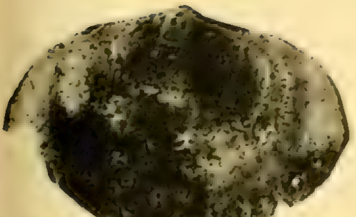
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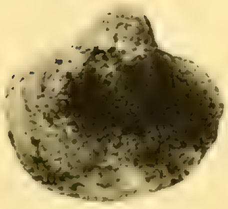
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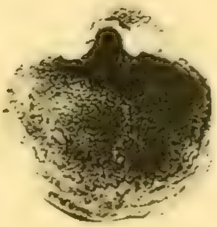
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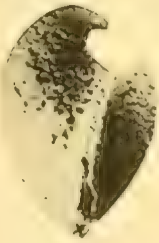
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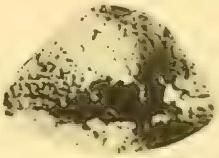
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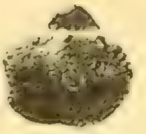
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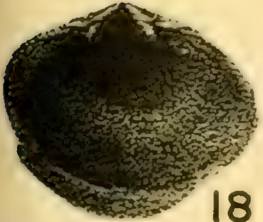
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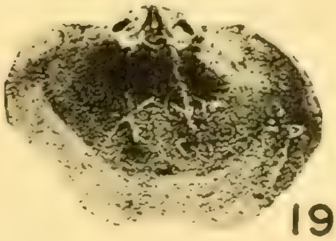
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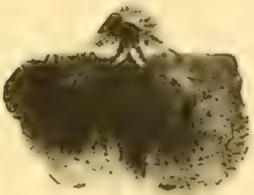
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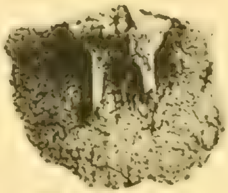
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PLATE 6 (11)

Explanation of Plate 6 (11)

Figure		Page
1,4,6.	**Phricodothyris perplexa** (McChesney)	50

1. Dorsal exterior showing the growth lamellae and the double-barreled spines. × 4. Univ. of Cincinnati Geol. Mus., No. 25264.

2. Dorsal interior showing the paranotothyrial ridges on either side of the notothyrium, the crural plates, and a vague suggestion of the muscle scars. × 4. Univ. of Cincinnati Geol. Mus., No. 25264.

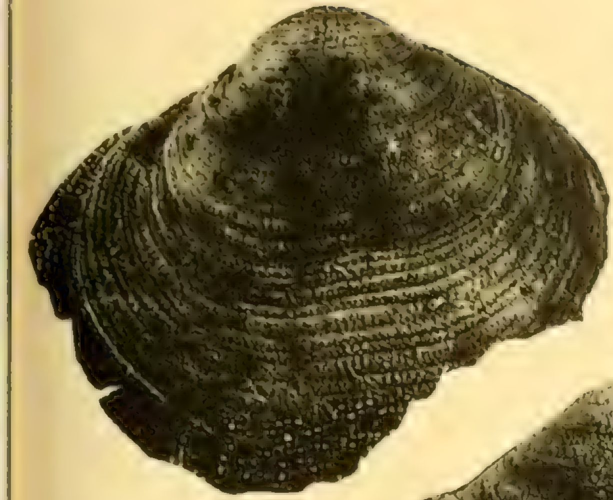
3. Ventral exterior showing the tear-drop shaped scars left behind where the double-barreled spines have broken off. × 4. Univ. of Cincinnati Geol. Mus., No. 25264.

4. Ventral interior showing the paradelthyrial ridges on either side of the delthyrium. × 4. Univ. of Cincinnati Geol. Mus., No. 25264.

6. Dorsal interior showing the rugose cardinal process area, the crural plates, and the dental sockets. ×4. Univ. of Cincinnati Geol. Mus., No. 25264.

5.	**Spirifer rocky-montani** Marcou	53

5. Dorsal interior showing the plates covering the groove-like dental sockets. × 4. Univ. of Cincinnati Geol. Mus., No. 25270.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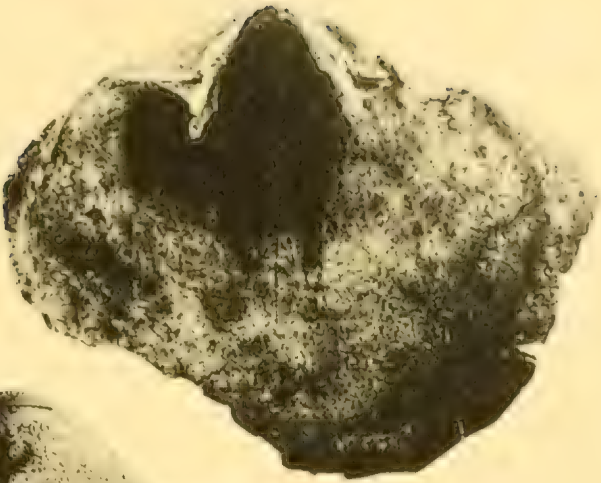
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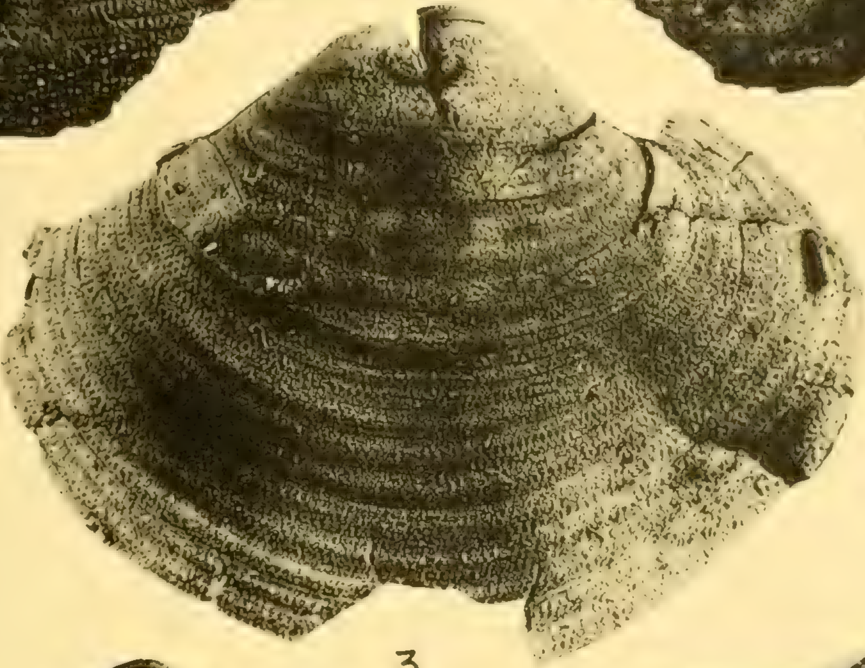
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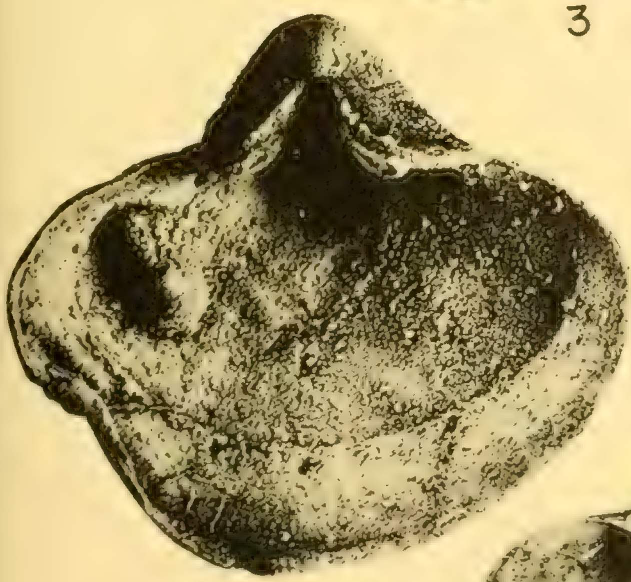
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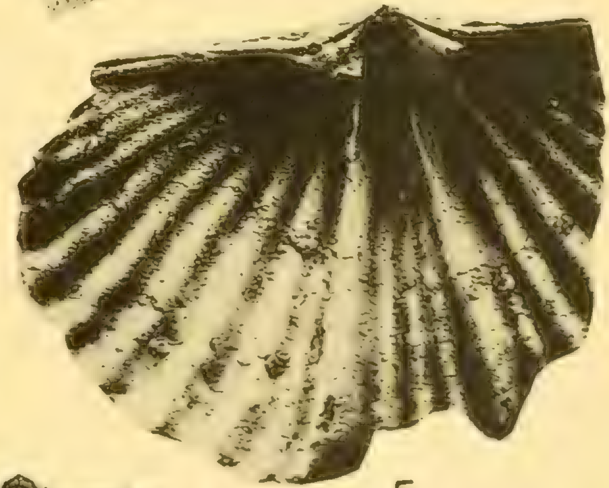
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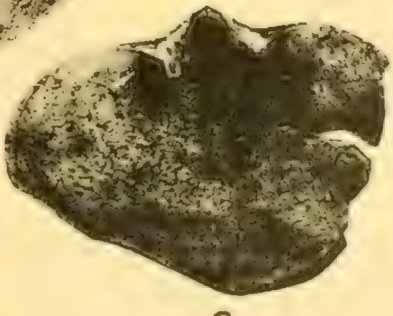
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PLATE 7 (12)

Explanation of Plate 7 (12)

Figure Page

1-6. **Punctospirifer transversa** (McChesney) 63

1. Dorsal interior showing the large cardinal process, the tenuous median septum, the muscle scar's encroachment onto the first pair of internal plications, the crural processes, and the punctae. ×4. Univ. of Cincinnati Geol. Mus., No. 25274.

2. Ventral interior showing the median septum. × 2. Univ. of Cincinnati Geol. Mus., No. 25274.

3. Ventral interior showing the median septum and the punctae. ×2. Univ. of Cincinnati Geol. Mus., No. 25274.

4. Posterior view showing the wide palintrope of the ventral valve. × 2. Univ. of Cincinnati Geol. Mus., No. 25274.

5. Dorsal exterior showing the many growth lamellae, the punctae, the slight median groove on the fold. ×2. Univ. of Cincinnati Geol. Mus., No. 25274.

6. Dorsal interior showing the large, boss-like cardinal process, the tenuous median septum, and the punctae. × 2. Univ. of Cincinnati Geol. Mus., No. 25274.

7-11. **Spirifer (Neospirifer) cameratus** (Morton) 57

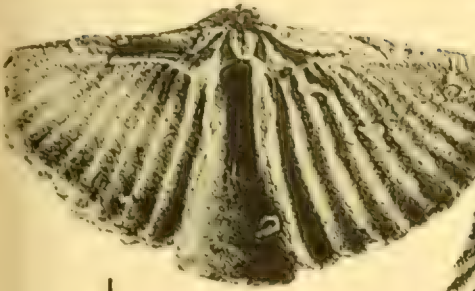
7. Ventral interior showing the teeth and the muscle scars. × 2. Univ. of Cincinnati Geol. Mus., No. 25271.

8. Ventral exterior showing the vague fasciculation of the plications. × 2. Univ. of Cincinnati Geol. Mus., No. 25271.

9. Ventral interior showing the muscle scars. × 2. Univ. of Cincinnati Geol. Mus., No. 25271.

10. Dorsal interior showing the crural processes. × 2. Univ. of Cincinnati Geol. Mus., No. 25271.

11. Dorsal exterior showing the vague fasciculation of the plications. × 2. Univ. of Cincinnati Geol. Mus., No. 25271.



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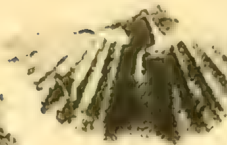

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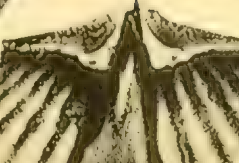

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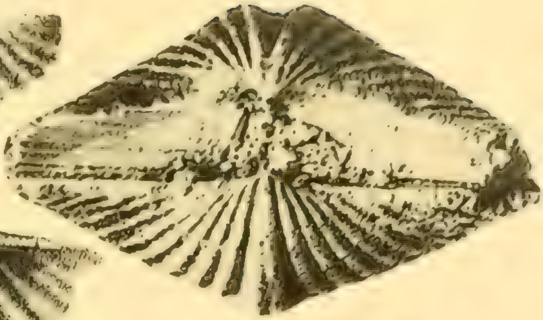

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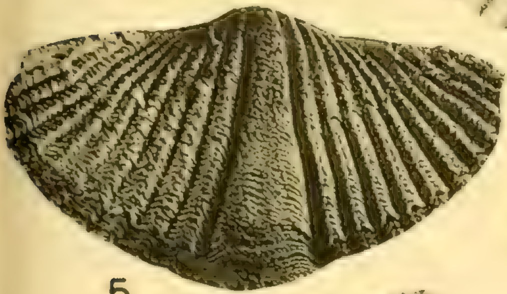

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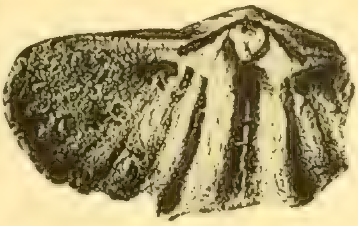

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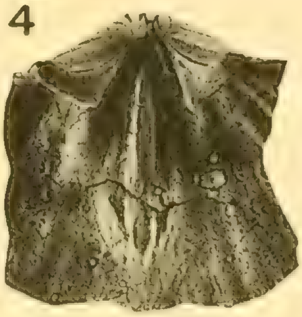

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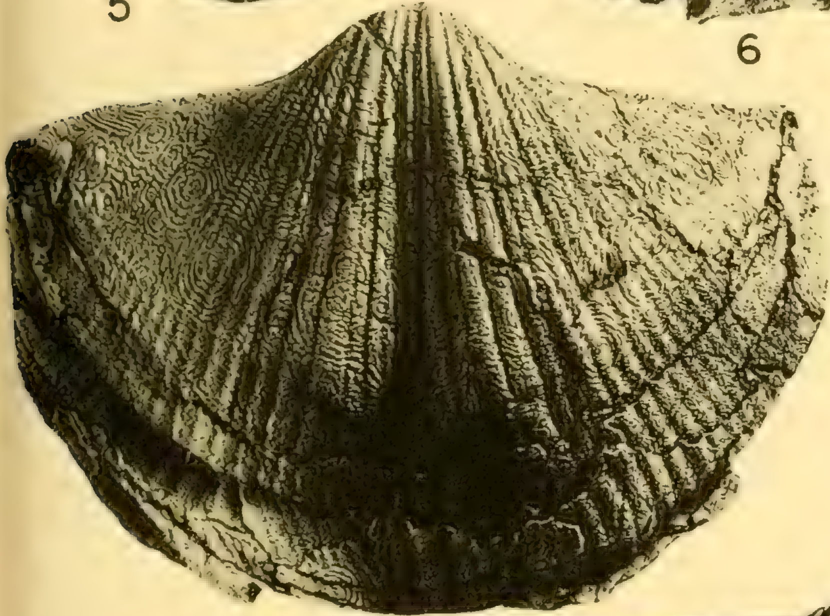

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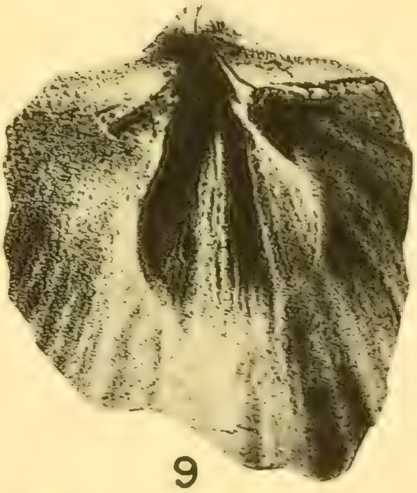

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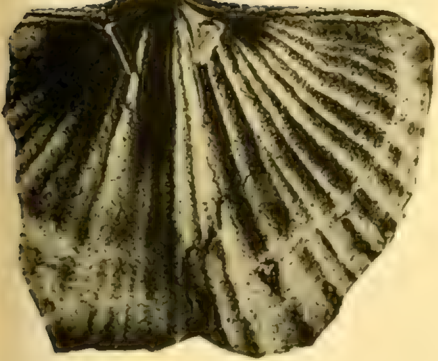

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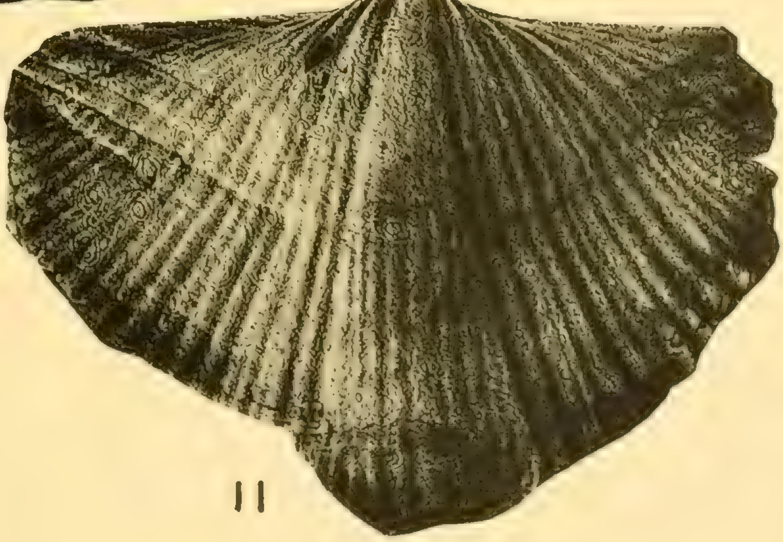

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PLATE 8 (13)

Explanation of Plate 8 (13)

Figure		Page
1,4.	**Spirifer (Neospirifer) cameratus** (Morton), variant	61

1. Dorsal view of an articulated specimen showing the acute angle between the palintrope and the lateral margin. × 1.5. Univ. of Cincinnati Geol. Mus., No. 25272. Holotype.

4. Ventral exterior of a very long specimen showing the acute angle between the palintrope and the lateral margin. × 1.5. Univ. of Cincinnati Geol. Mus., No. 25273. Paratype.

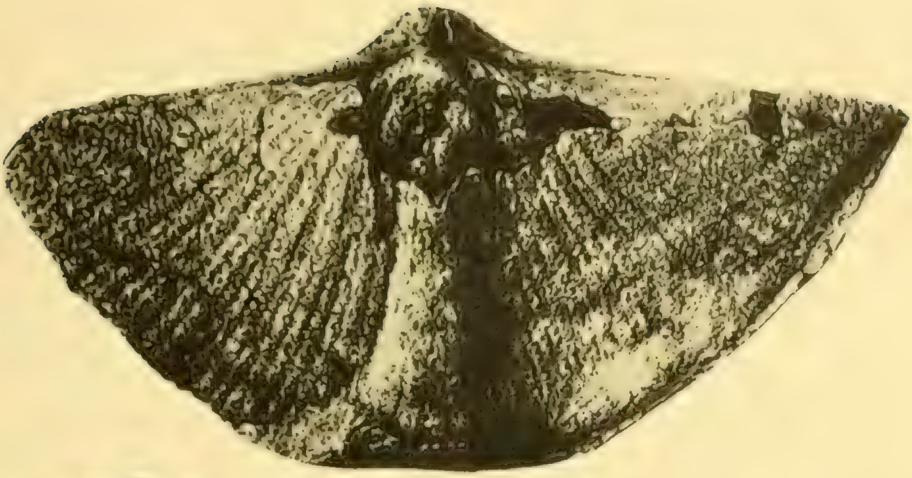
Figure		Page
2,3,5,6.	**Streptorhynchus hallianus** Derby	27

2. Ventral interior showing the anterior plications of the shell; the strongly developed muscular area, the teeth, and no median septum. × 2. Univ. of Cincinnati Geol. Mus., No. 25260.

3. Dorsal interior showing the massive bifid cardinal process, and the strongly developed median ridge between the muscle scars. × 2. Univ. of Cincinnati Geol. Mus., No. 25260.

5. Dorsal interior showing the same as Fig. 3. × 2. Univ. of Cincinnati Geol. Mus., No. 25260.

6. Postero-dorsal view showing the lobes of the cardinal process, one with two grooves. × 2. Univ. of Cincinnati Geol. Mus., No. 25260.



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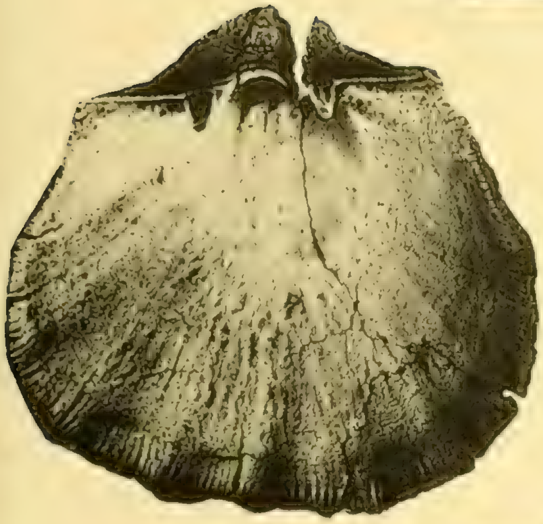

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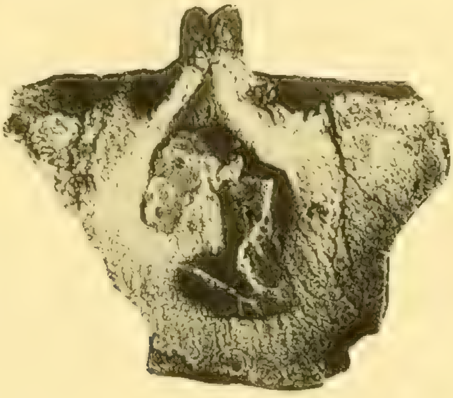

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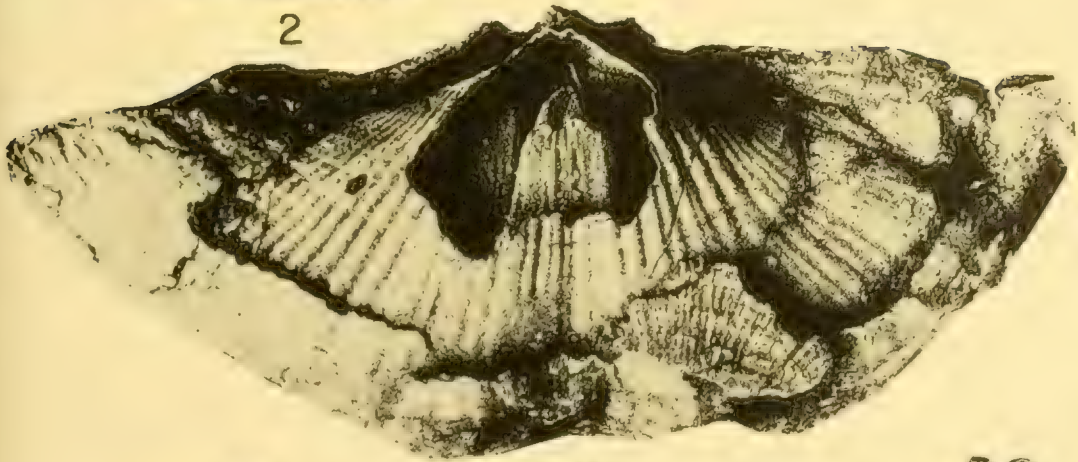

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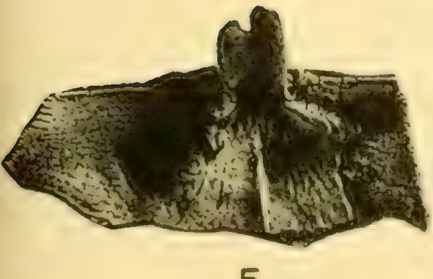

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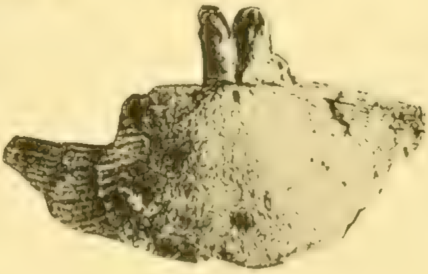

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EARLY ORDOVICIAN CEPHALOPOD FAUNA FROM NORTHWESTERN AUSTRALIA

By

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EARLY ORDOVICIAN CEPHALOPOD FAUNA FROM NORTHWESTERN AUSTRALIA

Curt Teichert and Brian F. Glenister*

ABSTRACT

A study of the rich Middle and Upper Canadian cephalopod fauna of the Price's Creek area forms the basis of the paper. Preservation in limestone has permitted detailed microscopic study. The time span of the fauna coincides with a critical period of rapid diversification of the nautiloid stock. The 26 new species are distributed amongst 24 genera (14 new) and 12 families (1 new). It is considered that the multiplicity of generic and familial categories in relation to the number of species is a true reflection of the explosive evolution of the early Ordovician nautiloids.

Ten of the genera are found only in North America and Australia, 2 genera are common to Europe and Australia, and 11 genera are indigenous. It is believed from these facts that there was an intermingling of littoral faunas between North America and Western Australia by some route which by-passed eastern Asia. Guyots may have served as an ecological bridge across the Pacific.

The terminology of the ectosiphuncle is revised. The terms orthochoanitic, suborthochoanitic, and holochoanitic are redefined, and the terms achoanitic, loxochoanitic, hemichoanitic, subholochoanitic, macrochoanitic, and ectosiphuncular suture proposed.

INTRODUCTION

In 1950, Guppy and Öpik published a brief note on the discovery of Ordovician rocks in the Kimberley Division of Western Australia. This announcement was momentous for two reasons. First, the new occurrence was geographically remote from any previously known outcrops of Ordovician rocks, the nearest being those of central Australia, 400 miles to the southeast. Secondly, the newly discovered section proved to be thick and fossiliferous and could be expected to provide important faunal links between the Ordovician of Australia and that of other parts of the world. The fossil collections made by geologists of the Bureau of Mineral Resources, Geology and Geophysics, contained many cephalopods which were submitted to us for study and description. The present paper presents the first description of a major faunal unit from this new Ordovician area and since Guppy and Öpik's publication is not easily accessible outside Australia, we have thought it advisable to quote extensively from its description of the locality and the section.

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OCCURRENCE AND HISTORY OF DISCOVERY

The Ordovician outcrops, which were discovered in 1949, cover approximately 12 square miles in what is known as the Price's Creek area of Christmas Creek Station (see Text Fig. 1). This locality is situated at 125°51′ E. long. and 18°42′ S. lat., about 180 miles east-south-east of Derby and 40 miles on a bearing of 145° from Fitzroy Crossing. It lies in the northeastern part of the Desert Basin, the largest sedimentary basin along the western margin of the Australian continent. Until 1949 it was generally believed that the oldest sediments in the Desert Basin were of Middle Devonian age (Teichert 1947a). Attention had been intermittently focused on this area by geological parties since 1919, when traces of mineral oil were reported in a shallow water well. As a result of this discovery five bores ranging in depth from 90 to 1008 ft. were drilled during 1922

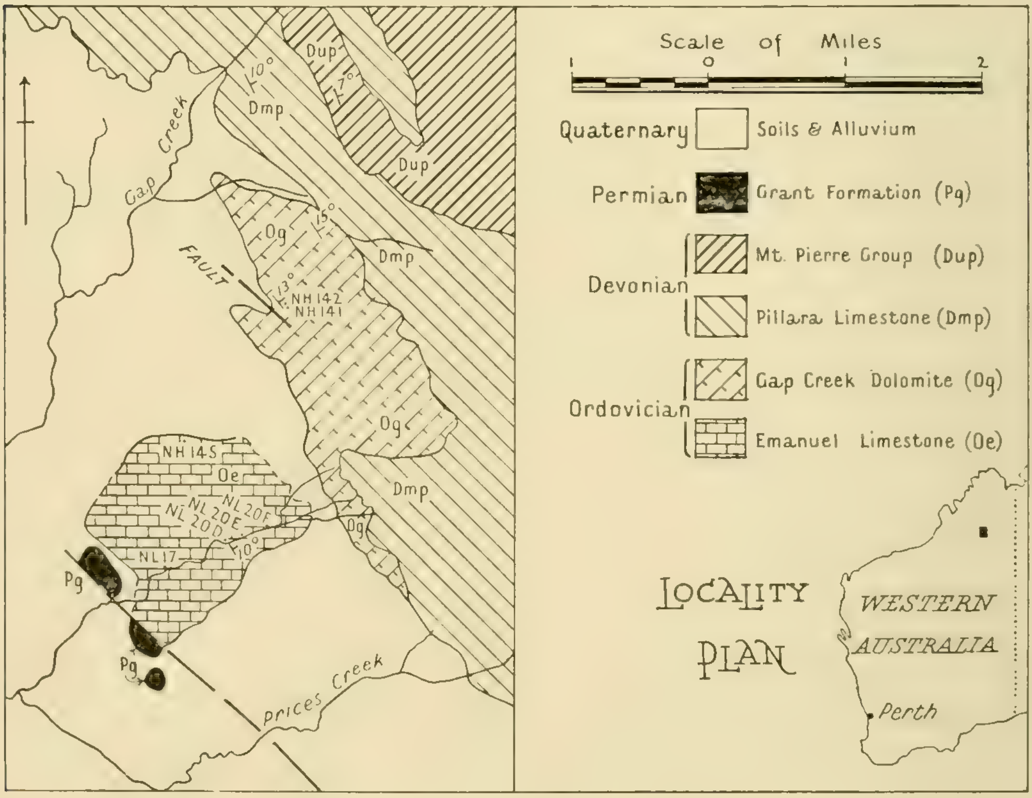
Scale of Miles
1
0
1
2
Quaternary
Soils & Alluvium
Permian
Grant Formation (Pg)
Mt. Pierre Group (Dup)
Devonian
Pillara Limestone (Dmp)
Gap Creek Dolomite (Og)
Ordovician
Emanuel Limestone (Oe)
Gap Creek
FAULT
Dup
Dmp
Og
Oe
Pg
10°
7°
15°
13°
NH 142
NH 141
NH 145
NL 20F
NL 20E
NL 20D
NL 17
Prices Creek
LOCALITY PLAN
WESTERN AUSTRALIA
Perth

Fig. 1. Geological sketch map of the Price's Creek area with index map of Western Australia in lower right hand corner. The undesignated creek which traverses the outcrop area of the Emanuel limestone is Emanuel Creek. (Map by courtesy of the Bureau of Mineral Resources, Geology, and Geophysics, Canberra).

and 1923; mineral oil was reported from four of the bores. The area had been included in a geological map by E. T. Hardman as early as 1887, when the rocks were shown as Carboniferous. In 1924, A. Wade reported on the same area, with a special view to the alleged oil occurrence, and he retained the notion of the Carboniferous age of the rocks concerned. Finally, a contour map of the Price's Creek area was provided with a more detailed geological report by Blatchford (1927) who, however, likewise failed to notice the presence of Ordovician fossils. From Blatchford's collections Prendergast (1935) described a plectambonitid brachiopod, *Spanodonta hoskingiae,* but gave its age as Devonian.

Recognition of the widespread occurrence of Devonian rocks in the Kimberley Division was due to the researches of L. V. Hosking (1932) who worked on collections made by Blatchford and others and demonstrated that most of the limestones shown as Carboniferous on all previous geological maps were actually Devonian. This was the age given to the rocks of the Price's Creek area in a revised map and detailed geological report printed as a company report by Wade in 1936. Later visitors included field parties of Caltex Australia Oil Development Pty. Ltd. in 1940, and of Vacuum Oil Pty. Ltd. in 1947. These parties likewise failed to find Ordovician fossils. For some years one of us (C. T.) suspected the presence of pre-Devonian rocks in the area from a number of *Eccyliopterus*-like gastropods in the Blatchford collections but failed to realize the importance of the occurrence of *Spanodonta;* he never had an opportunity of visiting the area himself. Significant collections were first made by D. J. Guppy and A. W. Lindner, in August 1949, while engaged in a general survey of the Devonian rocks of the Kimberley Division. The party was later joined by A. A. Öpik, who collected the bulk of the material which is now available.

At the end of 1949 all cephalopod specimens from these collections were sent to the senior author who, assisted by J. M. Dickins, made a preliminary survey of the material during 1950. Since 1951 the work has been carried on jointly by the authors of the present paper, and some preliminary results were incorporated in an earlier publication (Teichert and Glenister, 1952). In this paper the authors described two new genera, *Thylacoceras* and *Hardmanoceras,* and gave preliminary identifications of a number of other genera.

They determined the age of the bulk of the cephalopod material as Middle and Upper Canadian. A more detailed study of the fauna, based on a much larger number of thin sections, has led to a revision of some of the preliminary identifications. When the study of the initial collections had been all but completed, about 100 additional specimens were sent to us by O. P. Singleton, of the University of Western Australia, who visited the Price's Creek area in 1952. Although this material contained no new species, it contributed considerably to our knowledge of a number of forms.

We are greatly indebted to all the individuals concerned, including the Director of the Australian Bureau of Mineral Resources, Geology and Geophysics, for making this unique material available to us and for placing all relevant field data at our disposal. We also wish to record our thanks to Dr. R. H. Flower who has freely discussed with us many problems in relation to this paper and who has read and criticized the entire manuscript. We are indebted to the University of Melbourne for a financial contribution towards the cost of plates.

STRATIGRAPHY

The Ordovician sediments of the Price's Creek area are 2450 feet thick. They constitute the Price's Creek group (Guppy and Öpik, 1950) and are divided into two formations.

1. *Emanuel limestone.* This formation consists of 1670 ft. of light-grey limestone and calcareous shale. The lowest fossiliferous beds contain *Obolus* and hence are correlated by Guppy and Öpik with the Tremadocian and Ozarkian. Higher in the sequence *Xenostegium* appears, and still higher, limestones with a rich fauna of asaphid and pliomerid trilobites, gastropods, and nautiloids, with interbedded graptolite (dichograptid) horizons. The highest beds contain a genus of telephid trilobites which continues into the overlying formation.

2. *Gap Creek dolomite.* This formation consists of 780 feet of light-brown dolomite with narrow sandy bands. It contains an illaenid trilobite *(Bumastus?)* and the plectambonitid brachiopod *Spanodonta hoskingiae* Prendergast.

Based on a preliminary analysis of the fossil collections, Guppy and Öpik distinguished five "faunal stages" in the Price's Creek Group as follows:

See Table I, page 12.

PREVIOUS CORRELATIONS AND SOME CORRECTIONS

Guppy and Öpik correlated Stages II and III of the Emanuel limestone with the Canadian, Stage IV with the Chazyan, and the Gap Creek dolomite with the lower Trenton. The preliminary study of the cephalopods led us to suggest some changes (Teichert and Glenister, 1952). We correlated Stages II, III, and IV with the Middle and Upper Canadian, and the Gap Creek dolomite with the Chazyan. Our more detailed present studies have confirmed beyond doubt the correlations of the Emanuel limestone above the *Obolus* beds with the Middle and Upper Canadian, whereas the correlation of Gap Creek dolomite has not been substantiated.

By 1952 we had noted the prevalence in our material of orthoconic nautiloids "with straight marginal siphuncles which range from short orthochoanitic to full holochoanitic in structure and from eurysiphonate to stenosiphonate in size." It was stated that "most species can be assigned to such genera as *Endoceras, Baltoceras, Protobaltoceras*, and *Bactroceras*." However, detailed microscopic study of the siphuncular structure of these forms has since revealed that the species to which reference was made are best accommodated in new genera, which are described in the present paper.

Two additional genera which were wrongly identified and which also have to be removed from the faunal list of the Emanuel limestone are *Cyptendoceras* (erroneously spelled *Cryptendoceras* in our 1952 paper) and *Rudolfoceras*. The species which were believed to represent these two genera have likewise turned out to belong to previously unknown generic groups.

Some of these taxonomic changes have helped to put the correlation of Stages III and IV of the Emanuel limestone with the Middle and Upper Canadian on a more secure basis, particularly the removal of such genera as *Endoceras, Bactroceras,* and *Baltoceras*

TABLE I

Stratigraphic Units, Faunal Stages and Time—Correlation of the Ordovician in Price's Creek Area, W.A.

Stratigraphic Units		Faunal Stages	Faunal Sequence		Tentative Time-Correlation with Ordovician of U.S.A.
			Zone Fossils	Faunal Assemblage	
UPPER MIDDLE DEVONIAN	Pillara Limestone				
Unconformity					
LOWER AND MIDDLE ORDOVICIAN Price's Creek Group	Gap Creek Dolomite	V	*Spanodonta*	*Illaenus* (*Bumastus*) Pliomerids (*Ectenonotus* ?), *Isotelus*, several genera of gastropods, ostracods, etc.	Lower Trenton
	Emanuel Limestone	IV	Telephids	Asaphidae, Asaphellinae, Pliomeridae, Agnostidae, Clitambonitidae.	**Chazian**
		III	Dichograptids New genus of asaphids Nautiloids	Ostracoda, conodonts, Bellerophontacea, several genera of gastropods including *Plethospira.*	Canadian
		II	*Xenostegium*		
		I	*Obolus*		Upper Ozarkian
Base not seen					

Guppy and Öpik, 1950

which outside Australia seem to be restricted to beds of post-Canadian age.[1]

The identification of an endoceroid from the Gap Creek dolomite as *Meniscoceras* has been abandoned and this nautiloid now affords no basis for an age determination of that formation.

GENERAL ASPECTS OF THE CEPHALOPOD FAUNA

In this chapter some of the more interesting and significant features of the cephalopod fauna of the Price's Creek group are summarized. Subsequent chapters are devoted to the discussion of more specialized aspects. With the exception of one indeterminate species of Endoceratidae, all the cephalopods described in this paper came from the Emanuel limestone. This fauna is of singular interest, because no similar assemblage has been found anywhere else in Australia or on the neighboring continent of Asia. In fact, it is most nearly related to North American faunas, and these affinities will be discussed in more detail below. At first glance the collections did not appear promising, because many specimens were collected from river gravel and others are firmly embedded in hard limestone, from which they are difficult or impossible to free. However, preservation in limestone permitted detailed study of microscopic structures in thin sections, and it is possible that no single cephalopod fauna of the same age has previously been studied so thoroughly with regard to the structure of the septal necks and connecting rings. A wealth of new information can thus be presented.

It was found that the span of this fauna coincides with a critical period in the evolution of the cephalopods, during which holochoanitic septal necks developed from ellipochoanitic ones and eurysiphonate forms from stenosiphonate genera. Our material contains, at first glance, a bewildering array of combinations of narrow and wide siphuncles, and septal necks which range from achoanitic to holochoanitic in structure. Variety is increased by the appearance of annulated forms in which these characteristics may also be combined. Out of these observations arose the need for the more precise terminology of septal necks which is described in a later chapter.

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[1] Removal of *Bactroceras* from the faunal list of the Emanuel limestone does not affect the occurrence of this genus in central Australia, where it is represented by *Bactroceras gossei* (Etheridge) (see Teichert and Glenister, 1952). More recently, Glenister (1953) has recognized the genus in the Ordovician of New South Wales.

Regardless of length of septal necks, endocones began to appear in forms in which the siphuncle had reached a certain critical size. If the presence of endocones is regarded as a criterion of the Endoceratida, the Emanuel limestone contains the earliest known member of that order, a new genus here described as *Anthoceras*.

Altogether the cephalopod fauna of the Emanuel limestone, as here described, consists of 26 species, 2 of which have not been formally named. All of the species are restricted to the Emanuel limestone, and none of them has as yet been recognized from other areas. These 26 species belong to 24 genera, 14 of which are new (including 2 genera described by us in 1952). The 24 genera in turn are apportioned among 12 families, one of which is new.

The high proportion of generic and familial categories in relation to species may shock some readers. Authors who assign 26 species to 24 genera and 12 families must be prepared to face criticism for excessive "splitting." We have given much consideration to this aspect, and in every single case the decision to establish a new genus has been arrived at after mature deliberations and usually with a considerable degree of reluctance. We have had no preconceived ideas, observed facts have been our sole guide to interpretation, and we are convinced that the multiplicity of our generic and familial categories is an accurate expression of the evolutionary processes which dominated the expansion of the cephalopods in the early Ordovician period. This aspect will be again taken up for treatment in a later chapter.

In the following we propose to point out briefly the principal features of the Emanuel limestone fauna which make it so uniquely interesting to students of cephalopod evolution.

Four large orders of cephalopods are represented, the Ellesmeroceratida, the Endoceratida, the Discosorida, and the Tarphyceratida. In addition we have a representative of the genus *Bassleroceras* which Flower and Kummel (1950) made the type genus of an independent order, the Bassleroceratida. In our opinion the genera included in this order may well be regarded as primitive members of the Tarphyceratida.

In the Emanuel limestone the Ellesmeroceratida are represented by the following families: Ellesmeroceratidae, Eothinoceratidae, Protocycloceratidae, Baltoceratidae, and possibly a new family Thylacoceratidae. The Ellesmeroceratidae and Baltoceratidae are each represented by a new genus, *Loxochoanella* and *Hemichoanella* respectively. The Eothinoceratidae are represented by a typical species of *Eothinoceras* which has already been discussed by us in 1952. The Protocycloceratidae are in an unsatisfactory taxonomic state and the assignment of three genera from the Emanuel limestone to this group implies no more than general similarity to genera which have elsewhere been assigned to this family. The new family Thylacoceratidae has relationships both to the Ellesmeroceratidae and to the Endoceratidae and will be discussed in more detail below.

The Endoceratida are represented mostly by genera exhibiting primitive structures of this order. The Proterocameroceratidae (as defined by Flower, 1946) are represented by a form which we have referred to *Proterocameroceras* and which, even if it should be transferred to another genus, will remain in that family. In this family we also place *Anthoceras,* an annulate form with hemichoanitic septal necks (see chapter on terminology of septal necks). The Pilloceratidae are represented by the genus *Allopiloceras,* and the Endoceratidae by the straight genus, *Lobendoceras,* and two curved ones, *Cyrtendoceras* and *Campendoceras.*

Of particular interest is, furthermore, the occurrence of one new genus which appears to represent an early form of the Discosorida. Until recently this order was known only from beds of Black River and younger age, and extended into the Silurian. However, in 1940 Flower recognized *Ruedemannoceras* of the Chazyan as a primitive member of this group, and in 1952 we described a much larger and more advanced discosorid, *Madiganella,* from approximately Chazyan equivalents in central Australia. Pre-Chazyan discosorids may be expected to exhibit discosorid features in a more primitive state. Siphuncles should be smaller, and the connecting ring, though showing typical discosorid thickening, should be thinner than in later discosorids. The new genus *Apocrinoceras* possesses such features. It may represent a new family, but is, for the time being, regarded as an early westonoceratid.

Both families of the Tarphyceratida, the Tarphyceratidae as well as the Trocholitidae, are represented. In these families we have the genera *Aphetoceras, Pycnoceras* and *Arkoceras,* previously known from North America, as well as one European genus, *Estonioceras,* and two indigenous forms, *Hardmanoceras,* a trocholitid, and the tarphyceratid *Aethoceras,* the earliest known torticone ("trochoceroid").

While all the species described in this report are indigenous to the Price's Creek area of Western Australia, an analysis of the 24 genera reveals that 8 have not been recorded previously from outside North America. Of the 14 new genera described in this report, Dr. Flower reports that he has recognized two among material, as yet undescribed, from North America. This brings the total of genera common to the Ordovician of North America and Western Australia to 10. Twelve genera are thus far restricted to Western Australia, and only two have previously been known from Europe alone. These relationships will be considered in more detail below.

FAUNAL SUCCESSION AND CORRELATIONS

The present study was begun without detailed knowledge of field relationships and of vertical distribution of the species. Since a great many field numbers had been given to the specimens, it was assumed that specimens had been collected from narrow stratigraphical intervals. When we began to realize that the material might contain evolutionary series, particularly with regard to the development of septal necks and connecting rings, the exact succession of the species became of considerable importance. It was then that we learned with regret that owing to lack of time, sickness, and other unforeseen circumstances, only a rough stratigraphical grouping of the collections had been attempted in the field, and that loose specimens from the bed of Emanuel Creek had not been kept apart from material collected *in situ.* Since the Ordovician rocks in Emanuel Creek dip upstream there is thus a possibility of contamination of the collections downward in the section, but not vice versa. Attention will be paid in the following discussion to this condition.

A glance at Table 2 shows that collections from up to several hundred feet of strata have been mixed. Fortunately, the two most important and interesting assemblages have been defined within more narrow limits. These are the assemblages numbered NL 17 from beds 355 to 460 feet above the base of the Emanuel limestone and the one numbered NL 20E from the lower portion of that part of the section which lies between 1065 and 1170 feet.

In the following we shall discuss the distribution of the cephalopods in more detail. For the convenience of the reader, family relationships are given and repeated frequently in this discussion.

The lower 355 feet of the Emanuel limestone do not appear to contain cephalopods. Most or probably all of this part of the section represents Guppy and Öpik's "Stage I," which these authors correlated with the "Ozarkian."

From beds between 355 and 460 feet, which represent Guppy and Öpik's "Stage II," the following species have been identified:

Family Protocycloceratidae
    Kyminoceras forresti, n.gen., n.sp.
Family Eothinoceratidae
    Eothinoceras maitlandi n.sp.
Family Thylacoceratidae, n.fam.
    Lebetoceras oepiki, n.gen., n.sp.
Family Proterocameroceratidae
    Anthoceras decorum, n.gen., n.sp.
Family Trocholitidae
    Arkoceras sp.

This is an assemblage of extraordinary interest. There are five species representing five genera (three of them new) and five families (one of them new). Of these species, *Kyminoceras forresti, Eothinoceras maitlandi,* and *Arkoceras* sp. have not been found at higher stratigraphical levels and are, therefore, least likely to be contaminations from above. *Eothinoceras maitlandi* is considered to be the most important find, because it represents a genus which is so far known only from the Middle Canadian Rochdale limestone of New York State, where it is represented by *Eothinoceras americanum* Ulrich, Foerste, Miller and Unklesbay (1944).

Table 2. Distribution of the Price's Creek nautiloid fauna. Stages II-IV are in the Emanuel limestone, and Stage V represents the basal beds of the Gap Creek dolomite. A cross marks the stratigraphic position of the holotype of each species.

Age	M. Can.	Upper Canadian			?	Chazyan	
Stages of Guppy & Öpik (1950)	II	III			IV	V	
University of W. A. localities	E1	E10	E11				
Bureau Min. Resources localities	NL17	NL20D	NL20E	NH145	NL20F	NH141	NH142
Feet above base of section	355-460	460-1065	1065-1170		1245-1510	1670-1840	
Loxochoanella warburtoni			x				
Ectocyloceras inflatum			x				
Kyminoceras forresti	x						
Diastoloceras perplexum			x				
Hemichoanella canningi			—	x			
Eothinoceras maitlandi	x						
Thylacoceras kimberleyense		—	x				
Thylacoceras teretilobatum			x				
Lebetoceras oepiki	—	—			x		
Notocycloceras yurabiense		—	x	—			
Ventroloboceras furcillatum		x					
Proterocameroceras contrarium			x				
Anthoceras decorum	—	x					
Campendoceras gracile			x				
Allopiloceras calamus			x				
Cyrtendoceras carnegiei			x				
Lobendoceras emanuelense				x			
Endoceratidae gen. et sp. ind.						—	—
Bassleroceras annulatum			x				
Apocrinoceras talboti			x				
Aphetoceras delectans		x	—				
Aphetoceras desertorum			x				
Aethoceras caurus			x				
Estonioceras sp.		—					
Pycnoceras liratum			x				
Arkoceras sp.	—						
Hardmanoceras lobatum			x		—		

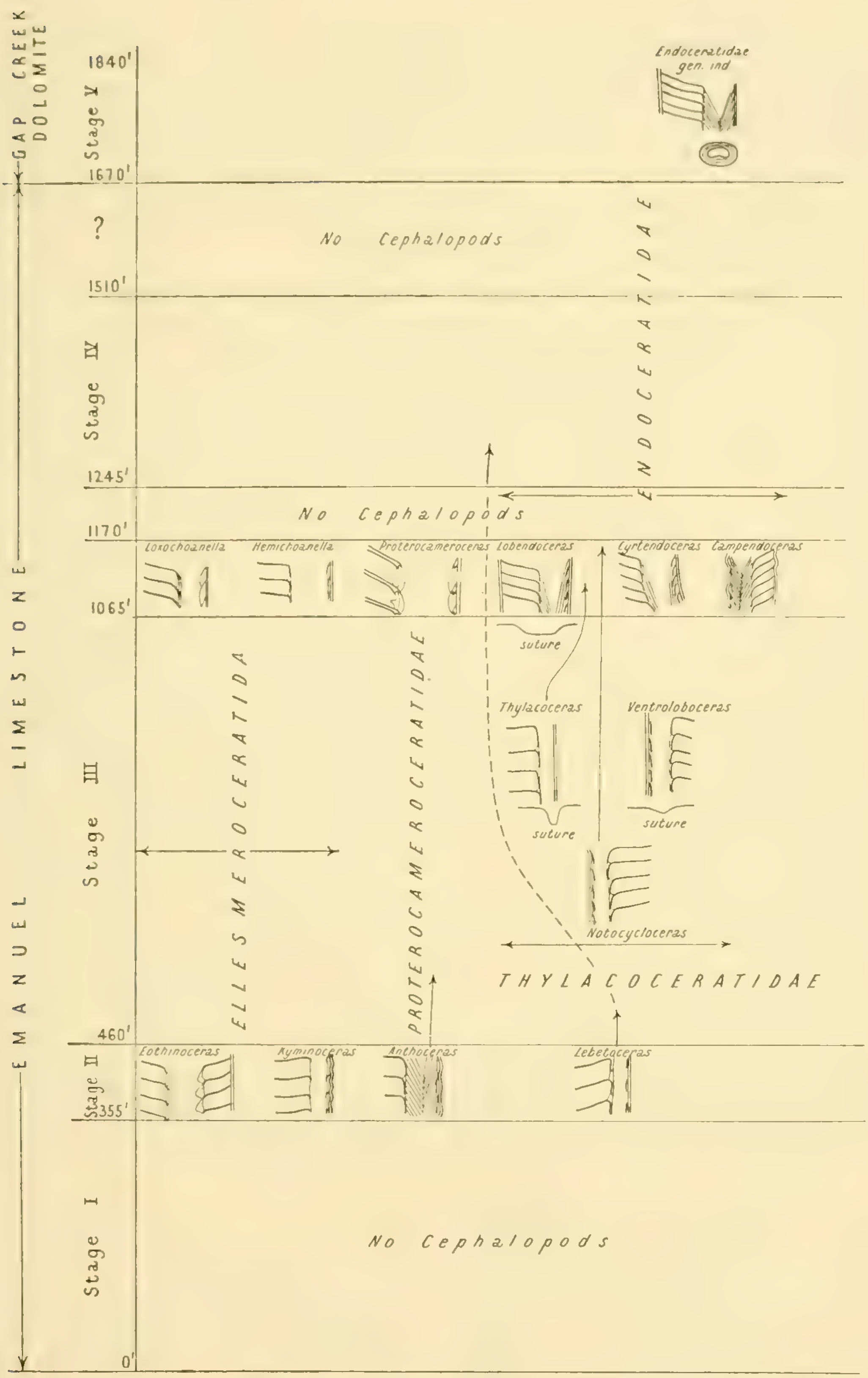

Fig. 2. Distribution diagram of the more important longiconic cephalopod genera from the Price's Creek area.

According to unpublished observations by Dr. R. H. Flower, *Kyminoceras* occurs in the Upper Canadian part of the El Paso limestone of southern New Mexico. Dr. Flower also informed us that he recognized *Anthoceras* from as yet undescribed material from the Upper Canadian Luke Hill formation at Philipsburg, Quebec, and one of us has been able to verify this identification by studying one of the specimens identified by Dr. Flower.

Arkoceras has, in North America, been reported from both Upper and Middle Canadian rocks. *Arkoceras exiguum* Ulrich, Foerste, Miller and Furnish (1942) occurs in the Smithville formation of Arkansas, which these authors regard as Upper Canadian. An unnamed form, *Arkoceras* sp., has been described from the Naylor Ledge limestone of southern Quebec, which Flower (oral communication) believes may be as old as Middle Canadian.

Thus, the assemblage from between 355 and 460 feet contains genera which in North America are either Middle Canadian *(Eothinoceras)* or Upper Canadian *(Kyminoceras, Anthoceras)* or occur in both *(Arkoceras)*. *Lebetoceras* has not yet been recognized outside Australia. Of these genera *Anthoceras* and *Lebetoceras* could be contaminations from higher beds.

In the absence of more detailed information on the stratigraphic occurrence of the species in this particular interval, it may be assumed that we are here concerned with transition beds between the Middle and Upper Canadian. The scale is perhaps weighed slightly more heavily on the side of Middle Canadian because of the high value for correlation which is ascribed to the genus *Eothinoceras*.

Above 460 ft. begins Guppy and Öpik's "Stage III" which is 710 ft. thick. The lower 605 feet, from 460 to 1065 ft., are not yet particularly rich in cephalopods, although more species occur than in "Stage II." The following species have been identified from the stratigraphic interval between 460 and 1065 ft.

Family Thylacoceratidae
  Lebetoceras oepiki, n.gen., n.sp.
  Notocycloceras yurabiense, n.gen., n.sp.
  Thylacoceras kimberleyense Teichert and Glenister
  Ventroloboceras furcillatum, n.gen., n.sp.
Family Proterocameroceratidae
  Anthoceras decorum, n.gen., n.sp.
Family Tarphyceratidae
  Aphetoceras delectans, n.sp.
  Estonioceras sp.

Anthoceras decorum comes up from "Stage II," where its occurrence may or may not be the result of downstream transportation. *Aphetoceras delectans* continues into the next higher group of beds, where it is associated with two additional species of the same genus. The occurrence at the 460 to 1065 ft. interval may, therefore, be due to downstream transportation, but this is not certain. Outside Australia, Tarphyceratidae are most common in the Upper Canadian, and it seems possible that the lower part of "Stage III" belongs to the early Upper Canadian, although a late Middle Canadian age would not appear impossible. The most important group in this assemblage seems to be the Thylacoceratidae. This family comprises a group of genera with narrow marginal siphuncles and long septal necks and has affinities with both the Ellesmeroceratida and the Endoceratida. It is probably most closely related to the former, representing a specialized branch which approaches the Endoceratida in certain characteristics.

The most important assemblage of cephalopods is found in the beds just above 1065 ft. and probably not higher than 1100 to 1120 ft. This comprises the following species:

- Family Protocycloceratidae
    - *Diastoloceras perplexum,* n.gen., n.sp.
    - *Ectocycloceras inflatum,* n.sp.
- Family Ellesmeroceratidae
    - *Loxochoanella warburtoni,* n.gen., n.sp.
- Family Baltoceratidae
    - *Hemichoanella canningi,* n.gen., n.sp.
- Family Thylacoceratidae, n.fam.
    - *Notocycloceras yurabiense,* n.gen., n.sp.
    - *Thylacoceras kimberleyense* Teichert and Glenister
    - *T. teretilobatum,* n.sp.
- Family Proterocameroceratidae
    - *Protocameroceras contrarium,* n.sp.
- Family Piloceratidae
    - *Allopiloceras calamus,* n.sp.
- Family Endoceratidae
    - *Lobendoceras emanuelense,* n.gen., n.sp.
    - *Campendoceras gracile,* n.gen., n.sp.
- Family Bassleroceratidae
    - *Bassleroceras annulatum,* n.sp.
- Family Westonoceratidae
    - *Apocrinoceras talboti,* n.gen., n.sp.
- Family Tarphyceratidae

Aphetoceras delectans, n.sp.
A. desertorum, n.sp.
Aethoceras caurus, n.gen., n.sp.
Pycnoceras liratum, n.sp.
Family Trocholitidae
Hardmanoceras lobatum Teichert and Glenister

This is a varied and interesting fauna in which the Upper Canadian element is unmistakable, due to the presence of such genera as *Proterocameroceras, Allopiloceras, Bassleroceras, Aphetoceras* and *Pycnoceras,* none of which has ever before been reported outside the Upper Canadian of North America.[2]

Since only two of the species listed above have been found in collections made from the upper part of the interval between 1065 and 1170 ft., it is concluded that practically the entire assemblage occurs *in situ* at a level not far above 1065 ft. Particularly noteworthy in this Upper Canadian fauna is the appearance of the first truly holochoanitic endoceratid, *Lobendoceras emanuelense.* Of particular interest are also the occurrences of typical ellesmeroceratids and baltoceratids, and the survival in strength of the Thylacoceratidae. Not less interesting is the appearance of what seems to be the earliest known discosorid, *Apocrinoceras.* Among the Tarphyceratidae, *Aethoceras,* the earliest known torticone is especially noteworthy.

In short, this fauna combines, in the most interesting way, survivors of more primitive ellesmeroceroid stocks with more modern endoceratids, tarphyceratids, trocholitids *(Hardmanoceras),* and forerunners of the still later discosorids.

Towards the top of the 1065-1170 ft. interval, cephalopods become quite rare. *Hemichoanella canningi* and *Notocycloceras yurabiense* seem to continue from the lower beds, and the only new arrival is *Cyrtendoceras carnegiei,* a holochoanitic curved endoceratid of European affinities. Species which may be expected to occur, because they have been found again above 1170 ft., are *Lebetoceras oepiki* and *Hardmanoceras lobatum.* The former species, however, is also absent from the rich horizons just above 1065 feet, and it is not impossible that its occurrence in the lower part of the section (between 355 and 1065 ft.) is in river pebbles only. Both species occur in the interval between 1245-1510 ft., just below the top of the Emanuel limestone. This is part, or all, of Stage IV in the succession of Guppy and Öpik, and indications are that this stage is still part of the Upper Canadian. *Cyrtendoceras* indicates a younger age, but the only available specimen of *Cyrtendoceras carnegiei* could have been transplanted downstream from higher beds.

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[2] Poulsen (1952) has recently reported *Proterocameroceras* from the Upper Canadian of East Greenland and from the Durness limestone of Scotland. Both these occurrences are from within the North Atlantic Ordovician faunal province.

None of the species of the Emanuel limestone continue into the overlying Gap Creek dolomite (Stage V of Guppy and Öpik) which has only yielded some unidentifiable fragments of an endoceratid and cannot, therefore, be dated on cephalopod evidence.

Our conclusions are thus only slightly at variance with the preliminary findings of Guppy and Öpik, who regarded Stage IV as Chazyan and the Gap Creek dolomite as Lower Trenton. If the latter correlation is confirmed, the possibility of a break in the sequence between the Emanuel limestone and the Gap Creek dolomite, representing at least part of the Chazyan-Black River interval, should be investigated in the field.

RELATIONSHIPS TO OTHER AUSTRALIAN CEPHALOPOD FAUNAS

Among described cephalopod faunas from Australia, only the one from Adamsfield in Tasmania is definitely known to be of the same age as the Emanuel limestone fauna.

It is peculiar that the two faunas have nothing in common (Teichert, 1947; Teichert and Glenister, 1952). At Adamsfield the east Asiatic element is characteristically represented by *Manchuroceras* and is associated with both American *(Piloceras)* and European *(Suecoceras)* elements. *Piloceras* must have come to Tasmania by the north Pacific route, by-passing east Asia. The fact that no element of the east Asiatic fauna reached Western Australia is difficult to explain. The answer may be found in southeast Asia, where Ordovician faunas are poorly known. It is possible that contemporaneous faunas also occur in Queensland, but these have not yet been described.

All other Tasmanian cephalopod faunas seem to belong to younger divisions of the Ordovician and the Silurian (Teichert and Glenister, 1953).

There is insufficient stratigraphical information available regarding the cephalopod faunas of central Australia to allow a correlation of faunas from different localities, and their generic composition has only been briefly surveyed (Teichert and Glenister, 1952). On the whole the fauna is most similar to that of the Baltic *Orthoceras* limestone, as evidenced by the association of large species of *Endoceras* with *Catoraphiceras, Baltoceras, Bactroceras,* and the slightly older *Bathmoceras*. A younger element is suggested by the presence of *Cyclendoceras* and *Armenoceras*. The presence of an unidentifiable genus of the Tarphyceratidae may indicate an older fauna, possibly contemporaneous with the fauna from the upper part of the Emanuel limestone. However, no close faunal links are known between the cephalopods of central Australia and those of the Price's Creek area.

From general considerations of the Ordovician palaeogeography of Australia it seems most likely that an Ordovician sea connected the general vicinity of the present Desert Basin, of which the Price's Creek occurrence forms part, with the area of deposition of the Larapintine formation in central Australia. Such a "Central Australian Geosyncline" was first postulated by Hills (1945) and has now been strongly confirmed. The clarification of the faunal relationships within this area of sedimentation must await more accurate stratigraphic collecting in all its parts.

RELATIONSHIPS AND ORIGIN OF KIMBERLEY CEPHALOPODS

It is intended in this chapter to consider in more detail the relationships of the Kimberley cephalopods and to present some conclusions as to their origin. As has been pointed out above, the fauna of the Emanuel limestone has no equivalent elsewhere in Australia. All its species are new, and none of them has, so far, been recognized in other areas. For the present, therefore, this fauna must be regarded as indigenous as far as species are concerned.

Considering the generic composition, some of the most interesting facts have already been briefly mentioned, and this chapter will be devoted mainly to a more detailed analysis of the genera and their affinities.

It will have been noted that, in the previous chapter, much emphasis was placed, for purposes of correlation, on the occurrence of certain genera. As a rule this is not good practice, because it is a well-known fact that genera may persist for different time intervals in different areas, and any genus may survive in isolated localities long beyond the acme of its existence elsewhere. However, we will attempt to show that special consideration in this respect must be given to the early Ordovician cephalopods.

The early Ordovician was a time of explosive or eruptive evolution of the cephalopod stock when, presumably due to an accelerated mutation rate, a number of basically new structural types developed in rapid succession and within a short space of time. Variation in the following morphological features is marked:

(1) *Septal necks:* Closely related forms exhibit wide variability in regard to the length of the septal necks. The range is from achoanitic through orthochoanitic, loxochoanitic, hemichoanitic, subholochoanitic and holochoanitic, to macrochoanitic (see chapter on terminology of septal necks).

(2) *Size of siphuncle:* A general tendency towards increase in the diameter of the siphuncle in proportion to the diameter of the shell culminates with the appearance of endoceratid forms.

(3) *Connecting rings:* The tendency is towards the thickening of the connecting rings and differentiation of it into layers.

(4) *Shell form:* Annulate shells occur together with smooth ones, and curved shells occur together with straight ones.

All these features are found in a considerable number of combinations, and all of our straight or nearly straight genera differ from each other in differences of combination of the above-mentioned characteristics.

Thus variations in the length of septal necks, complicated by variable shell features and sutures, are found among stenosiphonate forms (Thylacoceratidae) as well as more eurysiphonate groups (Proterocameroceratidae, Endoceratidae). Complexity of the connecting rings is not dependent on the length of septal necks, since complex rings may be present in subholochoanitic forms.

Combination and recombination of such transient characters, each of which is itself only a step in a series of changing morphological trends, must result in the appearance of short-lived biological forms which nevertheless are sharply distinguished and easily recognizable by means of well-defined morphological features. It is not likely that such types existed, as a rule, for long periods. It seems more likely that they would be extremely short-lived. Also, it is unlikely that such accidental combinations of rapidly developing morphological stages would be duplicated in different lineages in geographically separated populations. If such types are found in areas which are now widely apart, it is to be assumed that they represent derivatives from the same parent stock, even if differences on the specific level do exist.

The Emanuel Creek fauna contains a number of cephalopod genera which possess such a combination of specialized characters and which have never previously been reported outside North America. In the following we shall discuss these genera in detail, because a thorough understanding of their structures will result in far-reaching palaeogeographical conclusions. The genera which we propose to discuss and which are common to Australia and North America and to no other region are: *Eothinoceras, Kyminoceras, Anthoceras, Arkoceras, Ectocycloceras, Proterocameroceras, Allopiloceras, Bassleroceras, Aphetoceras,* and *Pycnoceras.*

Eothinoceras maitlandi, which occurs in the lowest cephalopod-bearing beds, agrees so closely with *Eothinoceras americanum* that it has only been described as a new species because the American form is not well enough known for the likeness of all shell features to be confirmed. The unique feature of this genus is its internally thickened connecting ring, forming a ridge with a V-shaped cross-section. Among Canadian faunas the genus is unique and its connecting ring is not of a type one would expect to develop in homochronous homeomorphs. It is true that *Cyrtocerina* of the later Ordovician has connecting rings which closely resemble those of *Eothinoceras.* Whether *Cyrtocerina* is a descendant of *Eothinoceras* has yet to be determined, but it would strain the imagination less to make this assumption than to assume that such a structure could evolve again at another time. We believe, therefore, that the American and the Australian species of *Eothinoceras* came from the same genetic stock.

Anthoceras has recently been recognized by R. H. Flower in the

Upper Canadian Luke Hill formation at Philipsburg, Quebec. Detailed comparisons cannot be made until this occurrence has been described. This genus presents the following unusual combination of features: annulate shell, hemichoanitic septal necks, and well-developed endocones. Flower has furthermore recognized *Kyminoceras* low in the Upper Canadian portion of the El Paso limestone of southern New Mexico. *Kyminoceras* is a protocycloceratid with annulate shell, narrow marginal siphuncle, short septal necks, and simple connecting rings.

Proterocameroceras combines short septal necks which bifurcate towards their edges, appearing pronged in cross-section, with complex connecting rings, and endocones. The Australian species differs in details of the suture but internally is identical with the American type species. *Proterocameroceras* occurs in the Upper Canadian of New York and has recently been reported by Poulsen (1952) from rocks of the same age in northeast Greenland and from the Durness limestone of Scotland. It is thus a genus which, outside Australia, is restricted to the Appalachian-North Atlantic province and is not found in the European-Baltic province.

The case of *Allopiloceras* is an interesting one. This is a straight, or nearly straight, piloceroid with close affinities to the Manchuroceratidae. The latter are a prolific group in the Canadian of Manchuria and Korea but do not number *Allopiloceras* among them in that area. *Allopiloceras* is widely distributed in the Upper Canadian of North America, where it may represent a connecting link with the cyrtoconic Piloceratidae. It never seems to have reached eastern Asia and its occurrence in Western Australia is most unexpected.

Bassleroceras is widely distributed in eastern and midwestern North America (Ulrich, Foerste, Miller and Unklesbay, 1944). It is characterized by a most unusual combination of features, namely exogastric condition and small marginal siphuncle, compressed cross-section, and broad lateral lobes in the sutures. Weak annulations characterize the Australian species as a regional variant of the American stock, all the members of which have smooth shells.

Arkoceras is the only genus of Trocholitidae with subcircular cross-section, lacking a dorsally impressed zone. The latter is also absent in *Wichitoceras,* but this genus has a strongly compressed whorl-section. The only two American occurrences of *Arkoceras* are from Upper Canadian rocks in Arkansas and Quebec. Perhaps the features of this genus are not so uniquely diagnostic, but its occurrences are significant.

Among the Tarphyceratidae, *Aphetoceras* and *Pycnoceras* represent somewhat intergrading forms. The former genus is set apart by its open coiling. In North America it occurs widely in the Upper Canadian, from Newfoundland to Arkansas. The Australian species agree in all respects, except that they are more strongly annulate. *Pycnoceras* is a more generalized form to which perhaps less weight should be attached. It has a weakly developed impressed dorsal zone.

In conclusion, we can state that nearly one-half of the cephalopod species of the Emanuel limestone fauna belongs to more or less specialized genera which elsewhere are known only from the North American Ordovician province. Not a single purely eastern Asiatic genus occurs in the Emanuel limestone.

The question of the relationships of the Western Australian and North American Ordovician faunas is, therefore, an exceedingly interesting one. It is clear that there must have been an exchange and intermingling of faunas between the two areas along a route which by-passed eastern Asia, and it is suggested that the only available route was across the Pacific Ocean. Since littoral faunas cannot cross a vast ocean barrier, it is necessary to assume a different palaeogeography of the Pacific in the Ordovician. Gregory (1930) assumed extensive vertical movements in the Pacific during the geological past, and the existence of large Pacific land masses during various times in the Paleozoic. Ruedemann (1929) earlier postulated the existence of a Pacific Ocean in Ordovician time, basing his conclusions on the presence in Australia and North America of certain specialized graptolite genera, such as *Oncograptus* and *Cardiograptus*. It is possible that both these authors were right.

The obvious fact of an interchange of littoral faunas between Australia and North America, as discussed above, leads us to postulate the existence of at least a sufficient number of stepping stones by which these faunas could have crossed over. Numbers of conveniently spaced islands would serve this purpose.

In this connection, it is possible to refer to Hess' original suggestion of a Precambrian age of the Pacific guyots (Hess, 1946).

These submarine sea mounts, which are being discovered in increasing numbers, were at first thought to represent Precambrian volcanoes which were eroded and later submerged in the early Paleozoic. As far as is known at present, the number and distribution of the guyots may be sufficient to account for a migration of littoral faunas across the North Pacific at any time at which they might have appeared as islands above sea level (see Teichert, 1953).

More recently a younger age of the guyots has been favoured by Hamilton (1951, 1952) because Cretaceous and Tertiary fossils have been dredged from the platforms of some of them. However, it may be said that the occurrence of Cretaceous and Tertiary shallow water fossils on the sea mounts suggests nothing more than that they were then covered by less water than now. It does not give a clue of the age of the mounts themselves. The necessity to postulate an ecological bridge across the Pacific in Ordovician times may lead to renewed consideration of Hess' original estimate of an older age of the guyots.

EARLY EVOLUTION OF THE ENDOCERATIDA

The order Endoceratida comprises cephalopods with shells which are generally straight and have large marginal siphuncles containing endocones. Advanced genera are holochoanitic, but early members have orthochoanitic or hemichoanitic septal necks. The first Endoceratida appear in the Middle Canadian, both in North America and in Western Australia. Their necks vary from achoanitic to subholochoanitic and they have straight shells which may be either smooth or annulate. To this group belong species of *Anthoceras, Clitendoceras,* and *Paraendoceras* which are at present included in the Proterocameroceratidae.

Endoceroids become more numerous in the Upper Canadian. *Proterocameroceras* is a specialized member of the order. It is large, has split septal necks and complex connecting rings, and is on the whole not a typical representative of the family to which it gives its name. The family Endoceratidae is characterized by holochoanitic septal necks. Dr. Flower informs us that no representatives of this family are as yet known from the Upper Canadian of North America. In Western Australia, however, at least one holochoanitic form *(Cyrtendoceras)* appears in an assemblage of Upper Canadian age, and there are two subholochoanitic genera associated with it, namely *Lobendoceras* and *Campendoceras*. All of these genera we include in the Endoceratidae, although *Lobendoceras* and *Campendoceras* are undoubtedly transitional between that family and the Proterocameroceratidae.

It is reasonable to suppose that the Endoceratida developed from cephalopods with smaller marginal siphuncles in which no endocones were developed. Endocones served the purpose of filling that space in the siphuncular lumen which was no longer occupied by the siphuncular organ. At the same time the added weight of the endocone deposits must have countered the buoyancy of the shell and thus helped to maintain the balance of the cephalopod animal. The formation of endocones is, thus, to a certain extent, a function of the size of the siphuncle. In the evolutionary history of the Endoceratida, endocones may be presumed to have appeared at a stage when the siphuncle had reached a certain critical size. The pre-endoceratids must have possessed straight shells, with marginal siphuncles which were smaller than those of typical endoceratids and which may also have had a tendency towards hemichoanitic and holochoanitic structure.

Genera in which such features are combined are found among two families, viz. the Baltoceratidae and the Thylacoceratidae. In both families the shells are straight or gently curved. The Baltoceratidae generally have rather large marginal siphuncles with orthochoanitic to hemichoanitic septal necks; the Thylacoceratidae have smaller marginal siphuncles with septal necks which tend to become holochoanitic. The taxonomic position of *Baltoceras* and its allies has been discussed. Holm (1897) and Schindewolf (1942) have maintained the endoceratid affinities of the genus, whereas Flower (1947) has insisted on its ellesmeroceratid relationships. Since the Baltoceratidae have wide siphuncles and yet no endocones, we agree with Flower and with Flower and Kummel (1950) that they should not be included in the Endoceratida. The Thylacoceratidae on the other hand have siphuncles of endoceratid appearance which are too small for endocones to have developed in them. When we first studied the type genus *Thylacoceras* (Teichert and Glenister, 1952) we included it in the Endoceratidae, but we now consider that this genus and the entire family Thylacoceratidae should not be included in the order related. We consider that the Thylacoceratidae of the Emanuel limestone represent a conservative stock from which the true endoceratids branched off early in, or perhaps immediately prior to, the Middle Canadian. The Thylacoceratidae may be regarded as an early Canadian offshoot of the Ellesmeroceratida, specializing in the direction of marginal siphuncles and elongation of the septal necks. We regard them as more truly intermediate between the Ellesmeroceratida and Endoceratida than the Baltoceratidae, because the latter, while specializing in marginal siphuncles, and partly also in increased size of siphuncles, did not develop the long septal necks which are a typically endoceratid feature.

The Thylacoceratidae and early Proterocameroceratidae seem to appear together in the lower part of the Emanuel limestone. It is to be hoped that more accurate palaeontological zoning on the basis of more exact stratigraphic collecting will be possible in the future, and that more light will thereby be thrown on the relationships between these two families. It is not impossible that the answer to the question as to the origin of the Endoceratida lies buried in the Emanuel limestone of Western Australia. Also, future zoning should help to establish important trends within the Endoceratida. Hemichoanitic *Anthoceras* is most probably the oldest genus. Subholochoanitic and holochoanitic Endoceratidae occur 600 to 700 feet higher in the section, but we have little knowledge of the intermediate faunas among which the Thylacoceratidae seem to dominate. While all these endoceroids have simple conical endocones with circular cross-section, more specialized forms with depressed endocones occur another 600 feet higher in the section. But again we have no knowledge of forms from the beds in between.

TERMINOLOGY OF SEPTAL NECKS

Several types of commonly occurring septal necks have long been known by the following terms:

holochoanitic—extending from one septum to the preceding septum or beyond;

orthochoanitic—short and straight, extending backward not more than a small fraction of the distance to the preceding septum;

cyrtochoanitic—short and curved, with distinct brim.

The two last-named types are occasionally grouped together and termed *ellipochoanitic*. It was Hyatt who, in 1883, first recognized these distinctions, and on them established two orders of nautiloids which he called Holochoanoidea and Ellipochoanoidea. However, it seems that Ruedemann, in 1906, was the first to use the above-mentioned terms in the adjectival form as part of the morphological terminology. More recently, Ulrich and Foerste (1933) added the

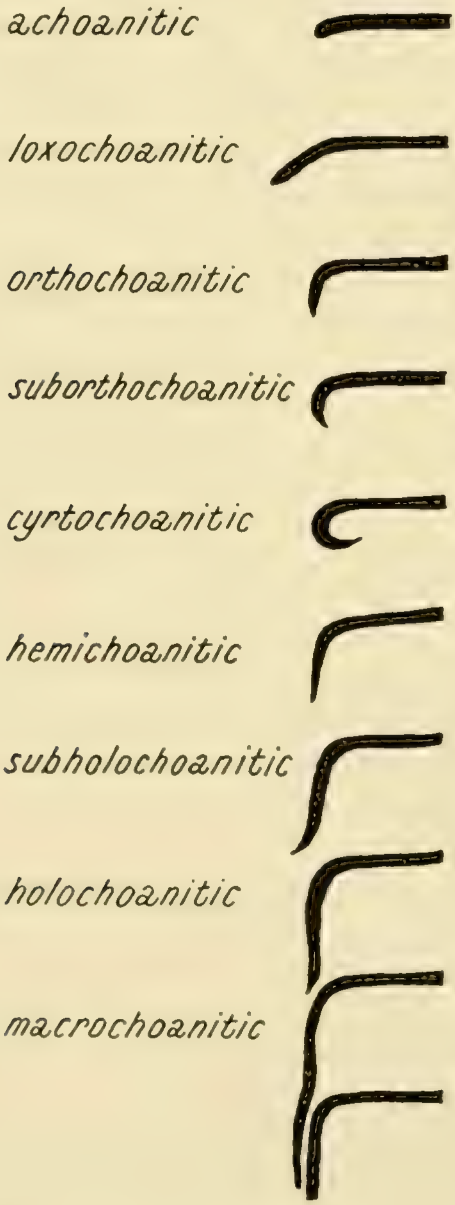
achoanitic
loxochoanitic
orthochoanitic
suborthochoanitic
cyrtochoanitic
hemichoanitic
subholochoanitic
holochoanitic
macrochoanitic

Fig. 3. Terminology of septal necks.

term *aneuchoanitic* for a condition in which the septal necks are either absent or vestigial. The term seems useful, though we propose to shorten it to *achoanitic* which has the same meaning. Furthermore, in 1941, Flower used the term *suborthochoanitic* for "cephalopods in which the septal necks are straight or curved, producing slightly convex siphuncular segments." Dr. Flower has since defined the term more precisely, in correspondence with the authors, as referring to septal necks which are usually slightly inclined outward at their tips but have no measurable brim.

During more recent investigations by Flower, and in the course of the present studies, additional types of septal necks have become known which are not covered by any of the existing terms. The following new terms are, therefore, proposed:

loxochoanitic—for septal necks which are short and straight and inclined inwards (in the direction of the central axis of the siphuncle);

hemichoanitic—for septal necks which are straight and extend from about one-half to three-fourths the distance to the preceding septum;

subholochoanitic—for septal necks whose length is approximately equal to the distance between two septa, but whose distal ends are deflected inward so that an appreciable gap exists between them and the proximal ends of the preceding septal necks. This gap is filled by a thick, often structurally complex, connecting ring.

It was also found convenient to restrict the term *holochoanitic* to septal necks which extend backward to the preceding septum and whose distal ends are in contact with, or in close proximity to, the proximal ends of the preceding septal necks. Connecting rings in such forms are vestigial or absent. The term *macrochoanitic* is here proposed for septal necks which extend backwards beyond the preceding septum. That is, in forms with necks of this type, successive necks are invaginated.

The following is a synopsis of septal neck terminology as here proposed (Fig. 3).

Achoanitic—septal necks absent or vestigial.

Orthochoanitic—short and straight, directed backyard.

Suborthochoanitic—short and straight, with slightly outwardly inclined tips but with no measurable brim.

Cyrtochoanitic—short and curved with well-defined brim.

Loxochoanitic—short and straight, pointing obliquely toward the interior of the siphuncle.

Hemichoanitic—straight, extending one-half to three-fourths the distance to the preceding septum.

Subholochoanitic—Approximately equal in length to the distance between two septa but deflected inward at their tips, thus leaving an appreciable gap between two successive septal necks.

Holochoanitic—essentially straight, extending backward to the preceding septum.

Macrochoanitic—essentially straight, reaching backward beyond

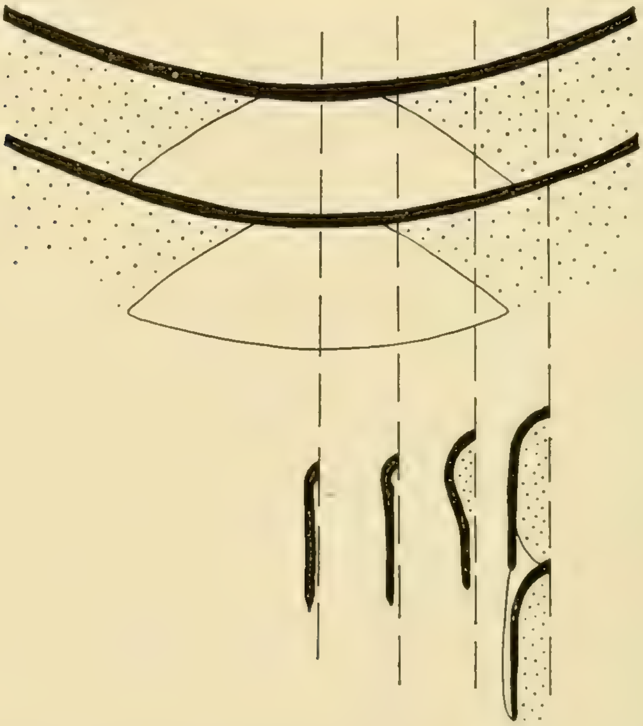

Fig. 4. Illustration of ectosiphuncular suture, consisting of a diagram of the ventral surface of two camerae (shell removed) and four longitudinal sections of the ectosiphuncle. The septa are represented by thick black lines. The unshaded area between the septa represents that area where the septal necks are flattened against the inner shell wall. An ectosiphuncular suture is present on either side of the mid-ventral line in each camera. They are the lines along which the gap between the septal necks and the inner shell wall becomes sufficiently wide for the introduction of matrix (dotted) between these two components of the conch.

the preceding septum, and invaginated into the preceding septal neck.

The siphuncle may be placed so close to the shell wall that the septal necks around part of the siphuncle are almost in contact with the inner surface of the shell. In several of the Price's Creek species, the space between the septal necks and the shell wall is such that the matrix which fills the remainder of the conch is not present in this area on the ventral side of the siphuncle. Preceding dorsally around the siphuncle from the mid-ventral line, the space between the septal necks and the shell gradually increases, until matrix is introduced between these two shell components. The term *ectosiphuncular suture* is hereby proposed for the line along which the septal necks become sufficiently separated from the shell wall for the introduction of matrix between these two components of the conch (Text Fig. 4). An ectosiphuncular suture is thus present in each camera on either side of the plane of symmetry of the conch.

TECHNIQUE OF STUDYING OPAQUE SECTIONS

Identifications of most early Palaeozoic cephalopods can generally only be made when cross-sections, preferably in the dorsoventral mid-plane, are available. It has long been customary to cut the specimens in such a way that the saw passes just to the side of the median line, so that one-half of the specimen presents a surface which is exactly in the median plane. This surface is then available for observation in reflected light by use of the binocular microscope. In order to increase the light penetration into the specimen and the clarity of surface observation, the surface was often polished. Other workers were satisfied with just wetting the surface or covering it with an oily or fatty substance. This generally proved to be unsatisfactory, since the fluids quickly evaporate and oily substances collect dirt. A large number of specimens were involved in the present investigations and the older techniques proved to be both time consuming and to some extent unsatisfactory. The following technique was evolved for our studies and can be recommended for similar work:

The specimen is first cut in a plane close to the surface in which the final section is required. A thin diamond saw is satisfactory for this purpose. The specimen is then ground down to the required plane, first on a coarse carborundum lap and finishing it by hand on a glass plate with very fine carborundum powder. When the surface is thoroughly dried, it is painted with a clear varnish which in Australia is known commercially as "Dulux." Any other clear varnish with an acetone base should be satisfactory. Brush marks often crinkle the surface at this stage, and bubbles are frequently trapped. Both bubbles and brush marks may be removed by spraying the surface of the varnish immediately with ether or some other highly volatile fluid capable of dissolving the varnish used. The ether has the effect of rendering the surface of the varnish less viscous. The surface, therefore, runs out more smoothly and on drying a surface of mirror-like gloss results. The varnish should be relatively quick drying and should not take more than two or three hours to harden. During this time the specimens should be kept under cover so as to prevent dust particles from settling on the glossy surface.

The specimens are now ready for examination under the binocular microscope. Here we find that the importance of a strong source of light cannot be overestimated. Ordinary desk lamps and microscope illuminators were found to be altogether too weak. We used a specially constructed illuminator consisting of a 50 Watt projector lamp mounted in front of a spherical mirror with a focal length of 12 inches. This lamp could be so adjusted by means of a ball and socket joint that the focal point of the mirror rested on the specimen under observation. We used a binocular microscope of the type which is mounted on a horizontal arm which swings around a vertical stem and the lamp was attached to the vertical stem. The intensity of the light beam is such that it penetrates some distance into the specimen. Surface features can be clearly observed under highest magnifications, and with certain types of preservation the structures of siphuncles and septal necks can be traced for a small distance below the surface of the section. The illuminator was constructed in the workshop of the Geology Department of the University of Melbourne by Mr. J. S. Mann to whom we are greatly indebted for a tool which has proved indispensable in our investigations.

We have no doubt that other varnishes and sprays and different arrangements for illumination will lead to similarly satisfactory results, as long as the combination of highest possible gloss with greatest possible intensity of illumination is achieved.

For photography we still had to rely on thin sections. Attempts to photograph surfaces prepared in the manner described above have not been successful, but we believe that proper combination of lens, filter, developing technique, and paper will eventually be found to give satisfactory results. However, our improved method of opaque observation enabled us to observe almost all structural features of the cephalopod siphuncle and shell and thus decide exactly which specimen or part of a specimen should be thin-sectioned for photography, thus eliminating any waste. This was of particular importance in the case of species of which few specimens were available.

SYSTEMATIC DESCRIPTIONS

Order **ELLESMEROCERATIDA**

Family **ELLESMEROCERATIDAE** Kobayashi, 1934

Genus **LOXOCHOANELLA** Teichert and Glenister, n.gen.

Type species.—*Loxochoanella warburtoni* Teichert and Glenister, n. sp.

Description.—Slowly expanding longiconic orthocones with smooth shell, circular cross-section, and moderately large marginal siphuncle; suture transverse and straight, except for a shallow ventral lobe; septal necks loxochoanitic; connecting rings thick and structurally complex, divided into a thin dense inner layer and a thick outer layer. The outer layer has undergone structural differentiation into a dense outer component and a coarse-grained inner component.

Affinities.—The thick complex connecting rings of *Loxochoanella* place this genus among the Ellesmeroceratidae. Close affinities between *Loxochoanella* and any other described genus do not exist.

Loxochoanella warburtoni Teichert and Glenister, n.sp. Pl. 2, figs. 1-4; text fig. 5

Description of holotype (No. 34122, Department of Geology, University of Western Australia; Pl. 2, figs. 1,3).—The holotype is an orthoconic phragmocone with circular cross-section. It has a length of 38.5 mm. and expands in diameter from 3.3 mm. at the

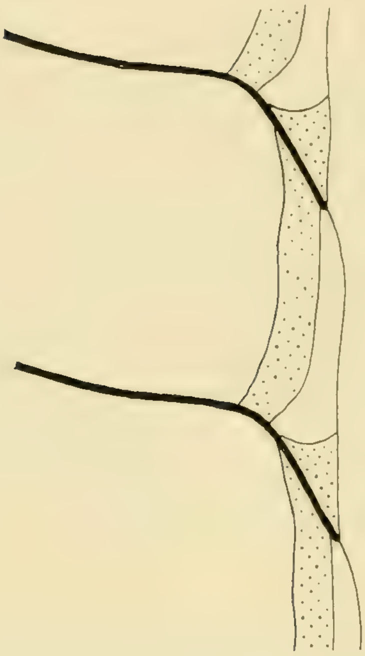

Fig. 5. Ectosiphuncle of *Loxochoanella warburtoni*.

posterior end of the specimen to 8.2 mm. at the anterior end. The siphuncle lies close to, but not in contact with, the ventral shell wall. Five and a half camerae together occupy a length equal to the shell diameter. Two camerae together occupy a length equal to the diameter of the siphuncle.

The suture is transverse and straight, except for a shallow rounded lobe across the venter. The internal mould of the shell is smooth.

A thin section of the anterior half of the specimen has been cut in the dorso-ventral mid-plane. The septal necks are straight and bent at an angle of 45° to the septa. This is the loxochoanitic type of septal neck, defined earlier in the paper. The siphuncular segments are concave. Two distinct components make up the connecting rings. The inner layer is thin and reaches backward from the tip of the septal neck to the tip of the neck which precedes it. The outer layer is much thicker. It originates on the outside of the septal neck, and reaches backward, covering almost the entire inner surface of the preceding septal neck. Where the shell has a diameter of 7.1 mm., the siphuncle has a diameter of 2.2 mm. and is situated .2 mm. from the ventral shell wall.

Description of paratype (No. 338, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 2, fig. 2).—This paratype is a slowly expanding longiconic orthocone with circular cross-section. It has a length of 35.5 mm., 4 mm. of which consists of body chamber. The diameter increases from 3.7 mm. at the posterior end of the specimen to 7.9 mm. at the anterior end. The siphuncle is marginal. It has a diameter of .9 mm. at the posterior end of the specimen. Six and a half camerae together occupy a length equal to the diameter of the shell. Two camerae together occupy a length equal to the diameter of the siphuncle.

The sutures are straight and directly transverse. Ectosiphuncular sutures are well developed where the shell is slightly worn. The shell is smooth.

A thin section of the posterior third of the paratype shows the septal necks to be loxochoanitic. The connecting rings are thick and consist of two distinct layers. The inner layer is uniformly thin and reaches posteriorly from the tip of one septal neck to the tip of the preceding neck. It is uniform in composition and appears to be constructed of finely crystalline dense material. The thick outer layer originates on the outer side of the septal neck, near its proximal end. It extends posteriorly and becomes adnate to the whole of the preceding septal neck and a small area of the septum adjacent to it. This outer layer exhibits structural differentiation, but the preservation is not sufficiently good for exact interpretation of the structures. However, it is clear that there is a concentration of dense fine-grained material on either side of the septal neck.

Description of paratype (No. 339, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 2, fig. 4).—The paratype is part of a phragmocone with a length of 19 mm. Five camerae together have a length equal to the shell diameter.

The septal necks are loxochoanitic, and, as in the holotype, the connecting rings are thick and complex in structure. Two layers may be discerned, a thin inner layer, and a thick outer layer. The inner layer is composed of dense material. It is convex inwards and only touches the septal necks at their distal extremities. The outer layer originates on the outside of the septal neck, where it is adnate to the distal two-thirds of the neck. It extends posteriorly and is adnate to the whole of the inner surface of the preceding septal neck, together with a small area of the septum adjacent to it. Structural differentiation of the outer layer is evident. A band of denser material originates on the outside of the septal neck and extends posteriorly to cover the inside of the preceding neck. A layer of coarsely crystalline material is left between this layer and the thin inner layer. Dense material is also concentrated at the posterior end of the connecting rings; that is, on the inside of each septal neck.

This species is named in honour of P. E. Warburton, who in 1873 was engaged in one of the first explorations of the Desert Basin.

Occurrence.—The holotype came from locality E 11 and both paratypes from locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Family **PROTOCYCLOCERATIDAE** Kobayashi, 1935

Kobayashi proposed this family for the two genera, *Protocycloceras* Hyatt and *Orygoceras* Ruedemann, but his conception of the family was based on Hyatt's erroneous description of the type genus. *Orygoceras* was later found to be preoccupied, and the name was replaced by *Rudolfoceras* Ulrich, Foerste, Miller, and Unklesbay (1944). In the same publication these authors erected the family Rudolfoceratidae for *Rudolfoceras, Ectocycloceras,* and *Seelyoceras,* whereas they included *Protocycloceras* in the family Spyroceratidae of Shimizu and Obata. However, as early as 1939 Flower had shown *Spyroceras* to be a member of the Pseudorthoceratidae. The genus is not closely related to *Protocycloceras* which, according to Flower's unpublished observations, has a fairly large siphuncle in subcentral to submarginal position, orthochoanitic septal necks, and complex connecting rings. *Rudolfoceras* is closely related, differing mainly in the possession of a more rapidly expanding, slightly exogastric conch. If the two genera are to remain in one family, as originally proposed by Kobayashi, the name Protocycloceratidae takes precedence.

Revision of the scope of this family would require detailed discussion of a great number of early Ordovician genera, some of which are only poorly known. For the present we include here annulated conchs, either straight or only slightly curved, with marginal to subcentral siphuncles of moderate size, and vestigial to short orthochoanitic septal necks. This definition also covers the Endocycloceratidae of Ulrich, Foerste, Miller and Unklesbay (1944), which differ from the Rudolfoceratidae only in being endogastric. In our opinion, slight differences in curvature among early Ordovician genera do not afford a safe basis for taxonomic differentiation of families. Our observations have taught us to place main emphasis on the size of the siphuncle and the nature of the structures associated with it (septal necks, connecting rings, siphuncular deposits). Shell features such as curvature and annulation should be relegated to an unimportant place.

In view of these conclusions, the grouping of the following three species with the Protocycloceratidae is far from satisfactory. Only *Kyminoceras forresti* is orthochoanitic, while both *Ectocycloceras inflatum* and *Diastoloceras perplexum* are achoanitic. All three species have small marginal siphuncles; the first two have annulate conchs, while *Diastoloceras* bears a remarkable series of transverse flanges. It is possible that these three species represent three different families, but too little about their affinities is known at present to make the erection of such new families advisable.

Genus **ECTOCYCLOCERAS** Ulrich and Foerste, 1936

Ectocycloceras inflatum Teichert and Glenister, n.sp. Pl. 1, figs. 5-6

Description of holotype (No. 370, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The holotype is an exogastric cyrtocone with a length of 42.4 mm., 28 mm. of which is body chamber. The siphuncle has a maximum diameter of .65 mm. and is situated .4 mm. from the ventral shell wall. At the posterior end of the specimen the dorso-ventral and lateral diameters are 7.7 mm. and 7 mm. respectively, while the dorso-ventral diameter at the anterior end of the specimen is 11.2 mm. Ten camerae together have a length equal to the dorso-ventral shell diameter.

The internal mould bears low rounded annulations and numerous fine lirae. Both the annulations and the lirae are directly transverse. The sutures are slightly sinuous and directly transverse.

The septal necks are achoanitic, and the siphuncular segments inflated. In a segment with a length of 1.25 mm., the segments are inflated to a maximum diameter of .65 mm., and constricted at the septal foramen to a diameter of .30 mm.

The species name refers to the inflated siphuncular segments.

Comparisons.—*Ectocycloceras inflatum* agrees with *Ectocycloceras cataline* (Billings), the type species of that genus, except that it is much smaller and has inflated instead of constricted siphuncular segments.

Occurrence.—Locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **KYMINOCERAS** Teichert and Glenister, n.gen.

Type species.—Kyminoceras forresti Teichert and Glenister, n.sp.

Description.—Prominently annulated slowly expanding orthocones with circular or subcircular cross-section; sutures sinuous and transverse; annulations transverse or sloping posteriorly from the dorsum to the venter, camerae low; siphuncle small and either marginal or situated close to the shell wall; septal necks orthochoanitic; siphuncular segments gently concave, cylindrical, or gently inflated; connecting rings thin.

The generic name is given in honour of Dr. B. Kummel.

Affinities.—Kyminoceras is closely related to *Protocycloceras* Hyatt, a genus which was thought to be holochoanitic (Foerste, 1921) but has recently been shown to be orthochoanitic with short septal necks (Flower 1947). Ulrich, Foerste, Miller and Unklesbay (1944) redefined *Protocycloceras* to include forms with either large or small, and marginal or submarginal siphuncles. They pointed out that it was somewhat doubtful if all the species included by them in the genus were congeneric and indicated that in the future it might be advisable to separate (1) those with large siphuncles from those with small siphuncles and (2) those with marginal siphuncles from those with submarginal siphuncles. Unfortunately, the structure of the ectosiphuncle of most of their species is unknown. Pending studies of their septal necks, six species included by Ulrich, Foerste, Miller and Unklesbay in the genus *Protocycloceras* are here grouped with the Western Australian species in the new genus *Kyminoceras.* They are *Kyminoceras doniphonense* (Ulrich et al.) *K. furtivum* (Billings), *K. manitouense* (Ulrich et al.), *K. odenvillense* (Ulrich et al.), *K. repens* (Billings) and *K. smithvillense* (Ulrich et al.). All have small marginal siphuncles and are of Canadian age. With the removal of those forms with small marginal siphuncles, the genus *Protocycloceras* is restricted to contain species with either large siphuncles or small siphuncles removed from the venter. *Walcottoceras* differs from *Kyminoceras* in having a strongly compressed elliptical cross-section.

All species included in *Kyminoceras* are of Canadian age, and where the ranges of the species are better known, they may be shown to be restricted to the Middle Canadian. *Kyminoceras forresti* occurs at the same stratigraphical horizon as the Middle Canadian species *Eothinoceras maitlandi.*

Kyminoceras forresti Teichert and Glenister, n.sp. Pl. 1, figs. 1-4; text fig. 6

Description of holotype (No. 34120, Department of Geology, University of Western Australia; Pl. 1, figs. 2-4).—The holotype is a slowly expanding orthoconic phragmocone, 21 mm. long. It is circular in cross-section and increases in diameter from 6.1 mm. at the posterior end of the specimen to 8.6 mm. at the anterior end. The siphuncle is small and marginal, increasing in diameter from 1.4 mm. at the posterior end to 1.6 mm. at the anterior end. Five camerae occupy a distance equal to the shell diameter.

The internal mould bears rounded annulations, six occurring on the holotype. These annulations slope posteriorly from the dorsum to the venter. The sutures are directed transversely, intersecting the annulations at an angle of about 5 degrees. They are sinuous, with lateral saddles and shallow rounded dorsal and ventral lobes.

The shell is slightly worn across the venter, thus giving a lateral section of the siphuncle. The septal necks are orthochoanitic. They are variable in length but have an average length equal to one-third the septal interval. The connecting rings are thin.

Description of paratype (No. 34121, Department of Geology, University of Western Australia; Pl. 1, fig. 1).—The paratype is a poorly preserved specimen which has been sectioned in the dorso-ventral mid-plane. The septal necks are variable in length. They are orthochoanitic and have an average length equal to one-third the septal interval. Most of the segments of the siphuncle are slightly inflated, but a few are cylindrical.

This species is named in honour of Sir John Forrest, noted Western Australian explorer and statesman of the 19th century.

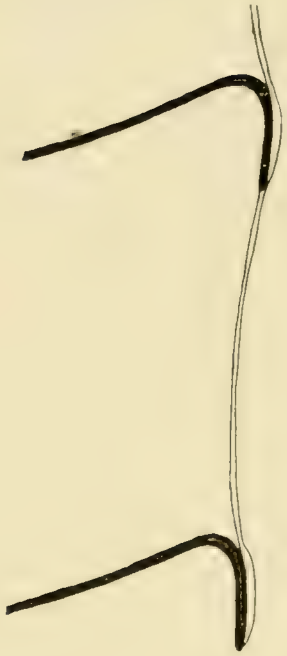

Fig. 6. Ectosiphuncle of *Kyminoceras forresti.*

Comparisons.—Kyminoceras forresti may be readily differentiated from other species of this genus by the relatively low angle the annulations make with the axis of the conch. More detailed comparisons cannot be made, since the exact structure of the siphuncle is unknown in all species of the genus except the type species.

Occurrence.—The type material and all known specimens of the species came from locality E 1, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **DIASTOLOCERAS** Teichert and Glenister, n.gen.

Type species.—Diastoloceras perplexum Teichert and Glenister, n.sp.

Description.—Slowly expanding gently cyrtoconic exogastric conchs with small, almost marginal, siphuncles; shell surface covered with well-developed transverse flanges; camerae short; siphuncular segments gently expanded, connecting rings thick, septal necks achoanitic.

The generic name refers to the remarkable flanges which traverse the shell.

Affinities.—The affinities of *Diastoloceras* are extremely difficult to determine. Comparable flanged forms are unknown in the Ordovician and are extremely rare in the Silurian. Only in the Devonian do they become common. The thickened connecting rings are similar to those of the Discosoroidea, but genera similar to *Diastoloceras* in other shell features are unknown among this order. *Diastoloceras* is included among the annulate Protocycloceratidae until closer affinities become apparent.

Diastoloceras perplexum Teichert and Glenister, n.sp. Pl. 1, figs. 12-16; text fig. 7

Description of holotype (No. 345, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The holotype and only known representative of this species, consists of a slowly expanding gently exogastric shell, 34.6 mm. long. The anterior 26 mm. are body chamber. The shell is circular in cross-section, having a diameter of 12.6 mm. at the posterior end of the specimen and 14.6 mm. at the anterior end. A broad constriction at the base of the living chamber restricts the diameter to 12.3 mm. At the posterior end of the specimen the siphuncle has a diameter of 1.5 mm. and is situated .5 mm. from the convex side. Eleven camerae together occupy a distance equal to the shell diameter.

The shell bears a remarkable series of transverse flanges, seven occurring in a distance equal to the shell diameter. They are thin and may project as far as 1.5 mm. from the general shell surface. The grooves between successive flanges are up to eight times the thickness of the flanges. The anterior surface of most flanges lies normal to the longitudinal shell axis, while the posterior surface slopes gradually posteriorly from the distal extremity to the base of the flanges. Each flange thus appears to slope forwards. The suture is sinuous and transverse. A shallow lobe occurs across the antisiphuncular surface and is flanked by a pair of low saddles, followed by a pair of shallow lobes across the flanks, and a low saddle across the siphuncular surface.

The septal necks are achoanitic. Siphuncular segments are

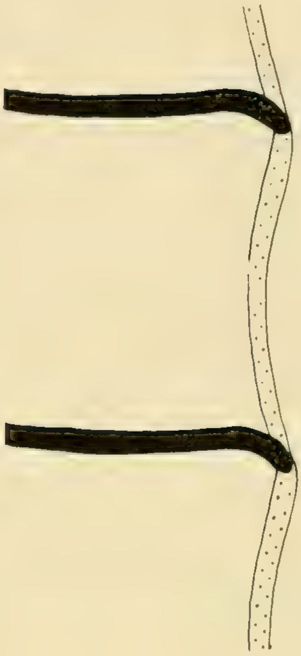

Fig. 7. Ectosiphuncle of *Diastoloceras perplexum.*

weakly inflated. The connecting rings are poorly preserved, but it seems probable that they were considerably thickened.

Occurrence.—Locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Family **BALTOCERATIDAE** Kobayashi, 1937

Genus **HEMICHOANELLA** Teichert and Glenister, n.gen.

Type species.—*Hemichoanella canningi* Teichert and Glenister, n.sp.

Description.—Orthoconic longicones with smooth shell, circular cross-section, and large marginal siphuncle; suture has deep narrow ventral lobe; camerae high; septal necks hemichoanitic, connecting rings thick and uniform in composition.

The generic name refers to the hemichoanitic structure of the septal necks.

Affinities.—*Hemichoanella* has affinities with both the Baltoceratidae and the Proterocameroceratidae. Under the system of classification accepted at present (Flower and Kummel, 1950), the genus cannot be considered as a member of the Endoceratida, since endocones have not been recorded. Neither can *Hemichoanella* be considered as a typical ellesmeroceratid, since the septal necks have advanced to the hemichoanitic stage. It thus seems advisable to consider *Hemichoanella* as a particularly advanced baltoceratid. *Baltoceras* differs from *Hemichoanella* in possessing orthochoanitic septal necks and particularly high camerae. The holotype of *Hemichoanella canningi* was referred to *Baltoceras* in a summary report on the Price's Creek nautiloids (Teichert and Glenister, 1952).

Hemichoanella canningi Teichert and Glenister, n.sp. Pl. 2, fig. 5; Pl. 3, figs. 1-4; text fig. 8

Description of holotype (No. 344, Bureau of Mineral Resources, Geology and Geophysics, Canberra.).—The holotype is a straight phragmocone, 37.8 mm. long. It is circular in cross-section and increases in diameter from 14.4 mm. at the posterior end of the specimen to 21.7 mm. at the anterior end. The siphuncle is large, marginal, and slightly depressed due to a ventral flattening. It increases in diameter from 4.9 mm. at the posterior end to 5.9 mm. at the anterior end. Six camerae together have a length equal to the dorsoventral diameter of the shell.

The suture consists of a deep ventral lobe followed by a pair of low saddles across the flanks and a broad but deep lobe across the dorsum. The ventral lobe is U-shaped. It has a breadth equal to the diameter of the siphuncle and a depth equal to the height of one and a half camerae. The shell is smooth except for the presence of numerous transversely directed fine growth lines.

The septal necks are hemichoanitic, having a length almost equal to half the length of a camera. The connecting rings are thick, and extend from the tip of the septal neck to the tip of the preceding neck.

The species is named in honour of A. W. Canning, who in 1906-1908 explored the eastern part of the Desert Basin and who discovered and opened up the Canning Stock Route.

Occurrence.—Emanuel Creek, Kimberley Division, Western Australia.

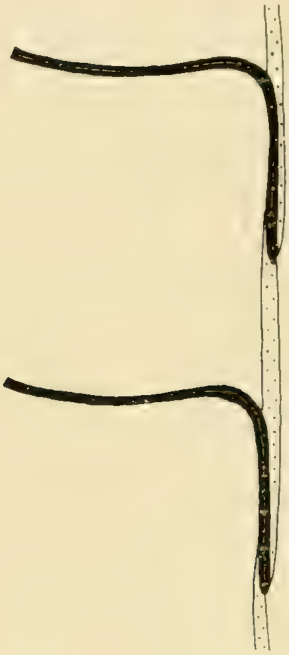

Fig. 8. Ectosiphuncle of *Hemichoanella canningi.*

Family **Eothinoceratidae** Ulrich, Foerste, Miller and Unklesbay, 1944

The family Eothinoceratidae was erected by Ulrich, Foerste, Miller and Unklesbay (1944) for the reception of a single new genus, *Eothinoceras*. The walls of the siphuncular segments of *Eothinoceras* were shown to be greatly thickened and V-shaped in longitudinal section, the apex of the V pointing inwards. *Eothinoceras americanum,* the only species of the genus, was described from a few poorly preserved fragments which had been ground and polished in planes of random orientation. The only forms referable to the family appeared to have straight breviconic conchs, with short camerae, and a large ventral siphuncle. They all came from the Middle Canadian Rochdale limestone of New York.

The family Cyrtocerinidae was established by Flower in 1946 with *Cyrtocerina* Billings as the only genus. Flower was of the opinion that *Eothinoceras* agreed with *Cyrtocerina* and with no other genus in the structure of the siphuncle, having achoanitic septal necks and highly inflated connecting rings. In a later paper Flower and Kummel (1950) included *Eothinoceras* with *Cyrtocerina* in the family Cyrtocerinidae. They considered *Eothinoceras* to be endogastric, with compressed shell and vestigial septal necks.

The structure of the connecting rings of the Australian species of *Eothinoceras* is almost identical with the connecting ring structures of *Eothinoceras americanum*, so that little doubt remains that they belong to the same genus. On the new information gained from the Australian species, the family Eothinoceratidae may be defined as follows:

Longiconic cyrtocones with a wide siphuncle close to the convex side of the conch. Septal necks short and orthochoanitic. Connecting rings greatly thickened and V-shaped in longitudinal section, the apex of the V pointing inwards. All known members of the family are probably confined to the Middle Canadian.

Cyrtocerina includes endogastric breviconic cyrtocones with marginal achoanitic siphuncles and connecting rings which are strongly inflated within the siphuncle. The genus is confined to the Middle and Upper Ordovician. Although the connecting rings of *Eothinoceras* and *Cyrtocerina* are similar, the two genera may not be closely comparable. It may thus be advisable to retain both the family Eothinoceratidae with its single genus *Eothinoceras*, and the family Cyrtocerinidae with the breviconic, endogastric *Cyrtocerina* as its only genus.

Genus **EOTHINOCERAS** Ulrich, Foerste, Miller and Unklesbay, 1944

Type species.—Eothinoceras americanum Ulrich, Foerste, Miller and Unklesbay, 1944.

The genus *Eothinoceras* may be redefined on information gained from the Australian species. It includes exogastric cyrtoconic longicones with a moderately large marginal siphuncle. The septal necks are short and orthochoanitic and the siphuncular segments concave externally. The connecting rings are greatly inflated and V-shaped, with the apex of the V occurring at about the mid-height of the segments, and pointing inwards. *Eothinoceras* is probably confined to rocks of Middle Canadian age.

Eothinoceras maitlandi Teichert and Glenister, n.sp Pl. 3, figs. 5-13

Description of holotype (No. 34123, Department of Geology, University of Western Australia; Pl. 3, figs. 9, 11).—The holotype is a fragment of a longiconic phragmocone with a length of 30 mm. Much of the outer part of the conch is deeply weathered, but it is probable that the cross-section was circular. At the anterior end of the specimen, both the lateral and dorso-ventral diameters measure

18 mm. The siphuncle has a diameter of 5.5 mm. and is situated close to the ventral shell wall. Fifteen camerae together have a length equal to the diameter of the shell and five camerae have a length equal to the diameter of the siphuncle.

The suture is not well seen, but it is probable that it was either straight or weakly sinuous. It slopes gently posteriorly from the dorsal towards the ventral side of the conch.

Weathering has exposed the siphuncle, giving a natural lateral section. The septal necks are orthochoanitic, with a length equal to about one-third of the septal interval. The connecting rings are extremely thick, and V-shaped in longitudinal cross-section. The point of the V corresponds to the thickest part of the connecting ring and is directed towards the inside of the siphuncle. The exact direction in which the apex of the V points is largely controlled by the angle of the sections. In oblique sections the connecting rings tend to point antero-laterally, but in longitudinal sections they are more nearly symmetrical. Each connecting ring originates at the tip of the septal neck. It thickens rapidly, so that the inside of the anterior limb of the V is almost directly transverse. This thickening continues to the apex of the V which lies at about the mid-height of the siphuncular segments. The posterior limb of the V slopes gradually to the area where it is adnate to the whole inner surface of the preceding septal neck. The outer surface of the connecting ring is traversed by a deep V-shaped groove just below the mid-height of the siphuncular segment. In a typical segment with a length of 1.2 mm., the length of the septal necks is .35 mm. and the greatest thickness of the connecting ring equals .8 mm. A tubular canal is present in the siphuncle. It is situated halfway between the ventral surface and the centre of the siphuncle and has a diameter of 2.5 mm.

Description of paratype (No. 335, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 3, fig. 13).—This paratype is part of a slowly expanding conch with a length of 90 mm., 22 mm. of which is made up of body chamber. It is gently cyrtoconic, with the siphuncle lying close to the convex side. At the posterior end of the specimen the conch has a diameter of 7.4 mm., while at the anterior end the diameter has increased to 17.5 mm. Near the posterior end of the specimen the siphuncle has a maximum diameter of 2.3

mm. and is situated .4 mm. from the ventral shell wall. Most of the siphuncle is missing, but the few fragments which remain show structures which are identical with those in the holotype.

Description of paratype (No. 336, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 3, fig. 10).—This paratype is a fragment of a phragmocone. An oblique thin section has been made through the centre of the siphuncle. The septal necks are variable in length but have an average length equal to about one-third of the septal interval. As in the holotype the connecting rings are greatly thickened, and V-shaped in longitudinal cross-section. The siphuncular segments are slightly concave but not to the same extent as those of the holotype.

The species is named in honour of the late A. Gibb Maitland, one of the pioneers of Western Australian geology.

Comparisons.—Detailed comparisons of *Eothinoceras maitlandi* and *Eothinoceras americanum* are difficult, since the American species is at present less well known.

Occurrences.—Holotype, No. 34123 and hypotypes, Nos. 34124-34126 (Pl. 3, figs. 6-8) came from locality E 1, and paratypes, Nos. 335-336 together with hypotypes, Nos. 337-338A (Pl. 3, figs. 5, 12) from locality NL17, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Family **THYLACOCERATIDAE** Teichert and Glenister, n.fam.

This family is here proposed for straight or slightly curved shells with small marginal siphuncle and subholochoanitic to macrochoanitic septal necks. As at present understood, it includes four Western Australian genera:

Thylacoceras Teichert and Glenister (1952), a genus with smooth shell, a deep and narrow ventral lobe of the suture, and subholochoanitic septal necks;

Ventroloboceras Teichert and Glenister, n.gen., with smooth shell, a broad and shallower ventral lobe of the suture, and holochoanitic septal necks;

Lebetoceras Teichert and Glenister, n.gen., with smooth shells, sutures running straight across the venter, and subholochoanitic septal necks;

Notocycloceras Teichert and Glenister, n.gen., with annulate shell and subholochoanitic septal necks.

In 1952 we included *Thylacoceras,* which was then the only known genus of this group, in the Endoceratidae, but the discovery of closely associated genera which all lack endocones seems to make it advisable to combine them in the new family here proposed.

It is possible that the family has representatives outside Australia and that some genera presently included in the Baltoceratidae and the Endoceratidae belong here, but lack of detailed information on the structures of the siphuncle and septal necks prevents useful discussion of most of them. *Bactroceras* Holm seems to be a closely related genus and provides a link with the Baltoceratidae. The relationships between the Baltoceratidae and the Thylacoceratidae have already been discussed.

Genus **THYLACOCERAS** Teichert and Glenister, 1952

Type species.—Thylacoceras kimberleyense Teichert and Glenister, 1952.

Description.—Gently tapering, slightly endogastric shells, with depressed shell cross-section; suture sinuous with a deep U-shaped lobe across the venter; siphuncle of moderate size and marginal position; septal necks subholochoanitic, connecting rings thick.

Affinities.—The combination of small siphuncle, subholochoanitic septal necks, smooth shell, and narrow U-shaped ventral lobe distinguish *Thylacoceras* from all other adequately known genera. *Pradoceras kobayashi* Sampelayo (1938) from the "ordoviciense medio" of Spain resembles *Thylacoceras* in possessing a small marginal siphuncle and deep U-shaped sutures across the venter. The camerae are, however, much deeper, and Sampelayo reported his genus as having a markedly constricted aperture. The siphuncular structures of *Pradoceras* are unknown.

Thylacoceras kimberleyense Teichert and Glenister, 1952 Pl. 6, figs. 2-5

1952. *Thylacoceras kimberleyense* Teichert and Glenister, Jour. Paleont., vol. 26, p. 738.

New collections of fossil material have increased our knowledge of this species, and redescription is warranted.

The conch expands slowly and is slightly curved endogastrically. It is depressed due to a flattening across the venter. The siphuncle is marginal in position and has a diameter equalling about one-fifth the dorso-ventral shell diameter. An average of eight camerae together have a length equal to the dorso-ventral shell diameter.

The sutures are conspicuously sinuous and transverse. A deep U-shaped lobe occurs across the venter. It has a depth equal to the length of one and a half camerae. The width of the lobe equals about two-thirds of its depth. The shell surface bears fine growth lines.

The septal necks have a length equal to more than two-thirds of the septal interval. Although typically somewhat shorter than most subholochoanitic necks, they may be described as subholochoanitic rather than hemichoanitic, since the general form of the ectosiphuncle is typical of subholochoanitic species. The septal necks are deflected inwards at their distal extremities. The connecting rings are thick and appear to be differentiated into a thin dense outer layer and a thicker and coarser-grained inner layer. The outer layer of the connecting ring originates on the outside of the septal neck slightly anterior to the tip and reaches backwards where it is attached to the preceding septal neck at its proximal extremity.

Occurrence.—Hypotype, No. 348 is from locality NL 20 D, and hypotype, No. 349 from locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia. Holotype No. 481 of *Thylacoceras kimberleyense* (Teichert and Glenister, 1952) came from locality NL 20 E (Bureau of Mineral Resources, Geology and Geophysics, Canberra).

Thylacoceras teretilobatum Teichert and Glenister, n.sp. Pl. 7, figs. 5-7

Description of holotype (No. 34127, Department of Geology, University of Western Australia).—The holotype is part of a slowly expanding phragmocone with slight endogastric curvature. It has a length of 72 mm. and is gently depressed in cross-section. The dorso-ventral and lateral diameters at the posterior end of the specimen, are 17.5 mm. and 18.2 mm. respectively, and the corresponding measurements at the anterior end of the specimen are 21.6 mm. and 21.9 mm. The siphuncle is marginal in position, its diameter being 3.4 mm. at the posterior end of the specimen and 3.7 mm. at the anterior end. Nine camerae together occupy a distance equal to the dorso-ventral shell diameter.

The sutures are sinuous and transverse. A broad shallow lobe occurs across the venter, and in the middle of this broad lobe lies a deep but narrow U-shaped lobe. The ventral lobe has a depth equal to two-thirds the length of a camerae; the width is slightly less than the depth. Numerous fine longitudinal striations occur on the internal mould, adjacent to the siphuncle. The shell is smooth.

The septal necks are subholochoanitic, having a length equal to the septal interval. They are deflected inwards at the distal extremities, so that a gap is left between the tip of the septal neck and the proximal extremity of the succeeding neck. This gap is filled by a thick connecting ring. The posterior half of each connecting ring is occupied by denser material than the anterior half. There is no indication of differentiation of the connecting ring into an inner and outer layer.

The species name refers to the delicate ventral lobe.

Comparisons.—This species is readily separated from *Thylacoceras kimberleyense* by its much narrower and shallower ventral lobe. The siphuncle of *Thylacoceras teretilobatum* is smaller than that of *Thylacoceras kimberleyense,* and the longitudinal striations which appear to be characteristic of the former, are unknown in the latter.

Occurrence.—Holotype No. 34127 is from locality E 11, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **LEBETOCERAS** Teichert and Glenister, n.gen.

Type species.—*Lebetoceras oepiki* Teichert and Glenister, n.sp.

Description.—Slowly expanding smooth orthocones with small marginal siphuncles. Septal necks subholochoanitic, connecting rings thick. Camerae low, sutures straight, and approximately transverse.

The generic name is derived from the Greek word for "Basin," a reference to the Desert Basin of Western Australia.

Affinities.—This genus is distinguished by the combination of small marginal siphuncle, subholochoanitic septal necks, and straight suture. *Protobaltoceras* Troedsson is superficially similar but has much shorter orthochoanitic septal necks. The type material of *Lebetoceras oepiki* was referred to *Protobaltoceras* in a summary report on the Price's Creek nautiloids (Teichert and Glenister, 1952).

Lebetoceras oepiki Teichert and Glenister, n.sp. Pl. 5, figs. 1-5; text fig. 9

Description of holotype (No. 340, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 5, figs. 1-2).—The holotype is a slowly expanding orthoconic longicone with a length of 60 mm. The conch is weathered across the dorsum, but it is almost certain that the cross-section was circular. The shell diameter is estimated to have been 16 mm. at the posterior end of the specimen and 21 mm. at the anterior end. The siphuncle is marginal and has a uniform diameter of 3.6 mm. Nine camerae together have a length equal to the shell diameter.

The shell is smooth. Abrasion of the outer surface of the conch has rendered the accurate tracing of the suture line impossible, but the suture appears to be straight and to slope posteriorly from the venter to the dorsum. A ventral lobe is not developed.

The whole specimen has been cut in the dorso-ventral midplane, and a thin section made of the posterior 16 mm. The septal necks are subholochoanitic, reaching slightly more than three-quarters of the distance to the preceding septal foramen. No textural differentiation has occurred in the thick connecting rings.

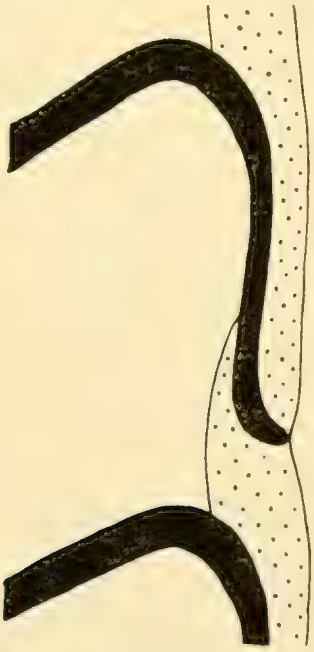

Fig. 9. Ectosiphuncle of *Lebetoceras oepiki.*

Description of paratype (No. 341, Bureau of Mineral Resources, Geology and Geophysics, Canberra; pl. 5, figs. 3-5).—The paratype is a phragmocone of circular cross-section with a length of 34 mm. The shell diameter is 17 mm. at the posterior end of the specimen and 19 mm. at the anterior end, while the siphuncle is marginal and has a uniform diameter of 3.4 mm. Little information is available concerning the suture except that it is straight and approximately transverse across the venter and flanks.

The ectosiphuncle is excellently preserved and consists of subholochoanitic septal necks joined by thick, homogeneous connecting rings. The septal necks reach slightly more than three-quarters of the distance to the preceding septal foramen and turn sharply inwards at their distal extremities.

This species is named in honour of Dr. A. A. Öpik.

Occurrence.—Locality NL 20 F (holotype) and locality NL 17 (paratype), Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **NOTOCYCLOCERAS** Teichert and Glenister, n.gen.

Type species.—Notocycloceras yurabiense Teichert and Glenister, n.sp.

Description.—Orthoconic longicones with small marginal siphuncle and well-developed annulations; shell cross-section slightly depressed, sutures straight; septal necks subholochoanitic; connecting rings thick and apparently homogeneous.

Affinities.—Notocycloceras is superficially similar to *Cyclendoceras,* from which it differs in having a smaller siphuncle and subholochoanitic instead of holochoanitic septal necks, and in the absence of endocones. *Catoraphiceras* differs in having a deep ventral lobe.

Notocycloceras yurabiense Teichert and Glenister, n.sp Pl. 5, figs. 6-7; Pl. 6, fig. 1

Description of holotype (No. 350, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The holotype is part of a slowly expanding orthoconic phragmocone with a length of 43 mm. A thin section of the anterior 16 mm. of the conch has been cut in the dorso-ventral mid-plane. The shell is elliptical in cross-section being slightly depressed. At the posterior end of the specimen the dorso-ventral and lateral diameters are 11 mm. and 12 mm. respectively, while the corresponding measurement at a point 27 mm. from the posterior end are 12.8 mm. and 13.8 mm. The siphuncle is small and marginal in position. It has a diameter of 3.4 mm. where the dorso-ventral shell diameter equals 12.8 mm. Eight camerae together have a length equal to the dorso-ventral shell diameter, and two camerae together have a length equal to the diameter of the siphuncle.

The sutures are practically straight and transverse. However, they slope posteriorly at a low angle from the dorsal to the ventral side of the shell. Ectosiphuncular sutures are well developed. The shell surface bears numerous well-developed annulations. They run parallel to the sutures and thus slope posteriorly from the dorsum to the venter. Four annulations occur in a distance equal to the dorso-ventral shell diameter. Numerous fine striations parallel the annulations.

The septal necks are subholochoanitic. They exhibit considerable variation in length, some being shorter than the septal interval and others longer. Each neck is deflected inwards at its distal end, so that a wide gap is left between it and the proximal end of the preceding septal neck. This gap is filled by a thick homogeneous connecting ring which extends from the tip of one septal neck to the tip of the neck which precedes it.

The species name is derived from Yurabi, the political division in which Price's Creek is situated.

Occurrence.—Holotype, No. 350 came from locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **VENTROLOBOCERAS** Teichert and Glenister, n.gen.

Type species.—Ventroloboceras furcillatum Teichert and Glenister, n.sp.

Description.—Slowly expanding orthocones with low camerae, and small siphuncle situated close to the ventral margin. Septal necks macrochoanitic, connecting rings thick. Broad but sharply rounded ventral lobe.

The generic name refers to the ventral lobe.

Affinities.—*Ventroloboceras* is not readily comparable to any other genus and occupies a special place even among the Thylacoceratidae, mainly because of its long septal necks. In this family it represents a homeomorph to the endoceratid condition with regard to septal neck development.

Ventroloboceras furcillatum Teichert and Glenister, n.sp. Pl. 7, figs. 1-4

Description of holotype (No. 356, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The holotype is a slowly expanding orthoconic phragmocone 27.5 mm. long. At the posterior end of the specimen the dorso-ventral and lateral diameters are 12.0 mm. and 12.2 mm. respectively, while the corresponding diameters at the anterior end of the phragmocone are 13.7 mm. and 14.0 mm. The siphuncle has a uniform diameter of 2.1 mm., and is situated .2 mm. from the ventral shell wall. Six and a half camerae together occupy a distance equal to the dorso-ventral shell diameter.

The internal mould is free of ornamentation. The suture line is composed of a broad but narrowly rounded ventral lobe, flanked by a pair of saddles across the ventro-lateral areas and a gently rounded lobe across the flanks and venter.

The septal necks are macrochoanitic, having a length which is slightly greater than the septal interval. Several of the better preserved septal necks are forked at their distal extremities. The outer branch of these forks almost touch the proximal extremity of the preceding septal neck (for typical macrochoanitic septal necks see text fig. 3). The connecting rings are moderately thick. There is a concentration of finely crystalline dense material at the anterior end of each connecting ring.

The species name refers to the forking of the septal necks at their distal extremities.

Occurrence.—Locality NL 20 D, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Order **ENDOCERATIDA**

Family **PROTEROCAMEROCERATIDAE** Kobayashi, 1937

This group was established as a subfamily by Kobayashi in

1937, but its diagnosis was based on erroneous descriptions of the type genus, mainly by Ruedemann. Flower (1946) restudied *Proterocameroceras*, showing that it was orthochoanitic and characterized by split septal necks and complex connecting rings. He established the family, Proterocameroceratidae. However, although it was Flower who first demonstrated the true structure of the type genus, the family name must be credited to Kobayashi.

The grouping of genera in this family is not satisfactory. Flower and Kummel (1950) include forms with septal necks ranging in length from vestigial to nearly the length of the camera. Some of the genera included by them are known only from isolated siphuncles (*Utoceras, Oderoceras*) and the length of their septal necks is not known. We are placing here the new genus *Anthoceras*. It is an annulate form, being the earliest annulate endoceratid so far known. The structures of the septal necks and connecting rings in *Anthoceras* are so different from those of *Proterocameroceras* that there is justifiable doubt of particularly close relationships between the two genera.

Genus **PROTEROCAMEROCERAS** Ruedemann, 1905

Proterocameroceras contrarium Teichert and Glenister, n.sp Pl. 4, figs. 1-4; text figs. 10-11

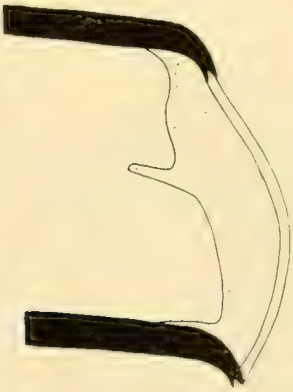

Fig. 10. Ectosiphuncle of *Proterocameroceras contrarium.*

Description of holotype (No. 366, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 4, figs. 1, 3-4).—The holotype is an internal mould, having a length of 115 mm., of which 58 mm. consists of phragmocone. It has been subjected to dorso-ventral crushing. The lateral diameters at the anterior and posterior ends of the specimen are 91 mm. and 77 mm. respectively. The dorso-ventral diameter at the posterior end of the specimen measures 39 mm., and the corresponding diameter at the anterior end 53 mm., but because of the crushing, these figures are somewhat lower than the original diameters.

The sutures are transverse and sinuous. A pronounced, but relatively narrow saddle occurs across the venter. It is followed by a broad shallow lobe, which gives place to a narrow ill-defined saddle on the ventro-lateral flank. The dorsal surface of the holotype has been crushed, and the sutures are not preserved along this part of the shell.

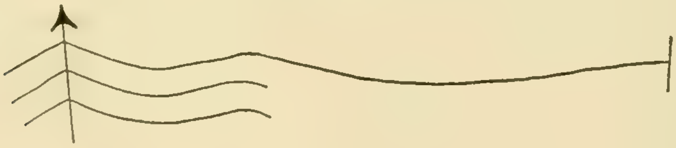

Fig. 11. Suture of *Proterocameroceras contrarium.*

At the posterior end of the specimen, the siphuncle has a diameter of 21.8 mm. and appears to have been almost in contact with the ventral wall of the conch. The septal necks and connecting rings are well preserved on the dorsal side but are missing on the ventral side. The septal necks on the dorsal side are excessively thick and short. In a typical siphuncular segment, with a height of 4.1 mm., the septal necks have a thickness of .5 mm. and a length of .45 mm. At their posterior extremities, the septal necks may generally be seen to bifurcate. The connecting rings are extremely thick and composed of two distinct layers. The inner layer is thin, having a uniform thickness of .15 mm. It reaches from the tip of one septal neck to the tip of the preceding septal neck. The outer layer is less regular and is progressively thickened towards the posterior end of the specimen. In more mature parts of the specimen this outer layer forms a projection into the camerae, producing a narrow flange situated just above the mid-height of the siphuncular segments. It exists only as a swelling of the outer layer in immature segments. The external layer continues as a thin deposit for a short distance along both the anterior and posterior surfaces of the septa. A layer of translucent calcite developed along the inside of the siphuncular wall doubtless represents recrystallized endocones. As would be expected, this recrystallized layer increases in thickness posteriorly.

Description of paratype (No. 367, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 4, fig. 2).—This specimen is a fragment from the ventral side of a phragmocone. The sutures are well preserved. It shows a sharply curved ventral saddle, followed by a wide lobe and another sharply curved saddle across the ventro-lateral area.

Description of paratype (No. 368, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—This paratype is a portion of a much larger specimen than the holotype. It has a length of 145 mm., a maximum lateral diameter of 135 mm., and a siphuncle whose estimated diameter is 34 mm. The conch has been crushed, and an estimate of the dorso-ventral diameter is not possible. Numerous fine, transverse growth lines are seen on a well-preserved portion of the shell wall. On the dorsal surface, the suture consists of a broad, low, saddle.

Description of paratype (No. 369, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The specimen has a length of 90 mm., 50 mm. consisting of phragmocone. It has been subjected to pressure in the dorso-ventral plane but is not greatly distorted. The dorso-ventral and lateral diameters measure 61 mm. and 77 mm. respectively at the posterior end of the specimen, while the corresponding diameters at the anterior end are 80 mm. and 103 mm.

Comparisons.—The similarity of the siphuncular structures of the Australian species of *Proterocameroceras* and *Proterocameroceras brainerdi,* the type species of the genus, (see Flower, 1947) can leave little doubt as to the close affinities between the two species. In the Australian species, three outward projections of the outer layer of the connecting ring occur in each siphuncular segment, one along the posterior surface of the septum, one just above the mid-height of the siphuncular segment, and one along the anterior surface of the septum. The first two projections are unknown in *Proterocameroceras brainerdi,* and the latter is only weakly developed. However, these projections are only developed in the mature part of our specimens, and the siphuncular deposits at the anterior end of the siphuncle are quite similar to those of the American species of *Proterocameroceras.* An unusally large, ventrally situated, and almost marginal siphuncle is common to both species. As far as can be determined from the crushed conchs of the Australian species, the conch proportions are similar to those of *Proterocameroceras brainerdi.* Important differences do occur in the details of the suture. The American species is described as having a directly transverse, somewhat sinuous suture, tending to form slight lateral saddles and similar dorsal and ventral lobes. The Australian species possesses a dorsal and a ventral saddle. Next to the ventral saddle is a broad rounded lobe, followed by a similar saddle across the ventrolateral area, and a broad lobe across the lateral and dorso-lateral area.

Although significant differences in details of both suture and siphuncle occur between the Australian species and the type species of *Proterocameroceras*, these do not seem to afford a basis for generic separation. The species name refers to the occurrence of *Proterocameroceras* on the opposite side of the earth to the type locality of the type species.

Occurrence.—All the types came from locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **ANTHOCERAS** Teichert and Glenister, n.gen.

Type species.—Anthoceras decorum Teichert and Glenister, n.sp.

Description.—Prominently annulated orthoconic longicones with circular cross-section; suture probably straight and transverse;

siphuncle moderately large and marginal, with constricted segments; septal necks subholochoanitic, connecting rings thick; endocones slightly asymetric.

The genus is named in honour of Dr. Rousseau H. Flower.

Affinities.—*Anthoceras* is best placed amongst the Proterocameroceratidae, although the septal necks are longer than those of typical members of this family. It differs from all other described genera in the combination of annulate shell, subholochoanitic septal necks, thick connecting rings, and complex endocones.

Anthoceras decorum Teichert and Glenister, n.sp Pl. 8, fig. 1

Description of holotype (No. 34129, Department of Geology, University of Western Australia).—The holotype is part of an orthoconic phragmocone with a length of 39.6 mm. Only one-half of the specimen is preserved, but it seems probable that the conch was circular in cross-section. The diameter at the posterior end of the specimen is estimated to have been 6.5 mm., and the corresponding diameter at the anterior end of the specimen 10 mm. The siphuncle maintains a uniform diameter of 2.8 mm. and is marginal. Six camerae together have a length equal to the shell diameter.

The shell is traversed by well-developed annulations, four occuring in a distance equal to the shell diameter. The holotype does not show the suture clearly.

The septal necks are subholochoanitic. They are variable in length, but most of them reach posteriorly almost to the preceding septal foramen. Unlike typical subholochoanitic septal necks, those of the holotype do not turn sharply inwards at their distal extremities. The necks are gently convex inward throughout their entire length, with the result that the siphuncular segments are slightly constricted at their mid-height. An appreciable gap is left between successive septal necks, and this gap is filled by the anterior part of the thick connecting rings. Numerous well-preserved asymetrical endocones fill the posterior half of the siphuncle. They are sinuous in cross-section. Many of them are deflected sharply outwards in the vicinity of the connecting ring, so that they meet it at right angles. A narrow endosiphuncular tube perforates the apices of the endocones. It is situated slightly nearer the ventral side than the dorsal side of the siphuncle and is crossed by several irregularly spaced diaphragms.

The species name refers to the beautifully preserved delicate structures of the siphuncle.

Occurrence.—The holotype was found at locality E 10, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia. Numerous specimens of this species are found at locality NH 143 near the base of the Emanuel limestone.

Family **PILOCERATIDAE** Miller, 1889

Genus **ALLOPILOCERAS** Ulrich and Foerste, 1936

Allopiloceras calamus Teichert and Glenister, n.sp. Pl. 7, figs. 8-9

Description of holotype (No. 355, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The species is known by the posterior portion of a single siphuncle. The holotype has a length of 54.5 mm. and at the anterior end of the specimen attains a dorsoventral diameter of 27.6 mm. and a lateral diameter of 24.7 mm. It is compressed throughout. The posterior third of the specimen expands rapidly, but the rate of expansion decreases anteriorly. The dorsal profile is convex in the posterior half of the specimen but becomes flat in the anterior half. The ventral profile is convex in the posterior third of the specimen, becomes gently concave to a point just anterior of mid-length, and then becomes gently convex in the anterior half of the specimen. The curvature is thus reversed in the anterior part of the siphuncle. Transverse annulations do not occur, although the siphuncle does not appear to have suffered severe abrasion. A deep but narrow groove starts at the apex and traverses the ventro-lateral flank. Six mm. from the apex it bifurcates to form two slightly sinuous grooves which traverse the whole length of the specimen. One of the grooves lies approximately in the mid-ventral plane, while the other traverses the ventro-lateral flank. Recrystallization has obliterated most of the finer internal structures, but both furrows appear to be continuous with irregular endosiphuncular blades. Five other endosiphuncular blades occur, and in each case they leave some trace of a longitudinal furrow where they meet the external surface of the siphuncle.

In cross-section the siphuncle is seen to be composed of a finely crystalline irregular outer layer, which probably represents recrystallized endocones, and seven unevenly spaced endosiphuncular blades which radiate from the central rod of dark-coloured calcite. This central rod may represent the endosiphuncular coleon and the endosiphuncular tube. The endosiphuncular coleon and the inner parts of the endosiphuncular blades are enclosed in coarsely crystalline calcite.

Comparisons.—The Australian species of *Allopiloceras* is a typical member of the genus. It has close affinities with *Allopiloceras sevierense* Ulrich, Foerste and Miller. Both species have siphuncles which expand uniformly near the posterior end, and in both the curvature is reversed at an early stage of development. The Australian species of *Allopiloceras* is the only representative of the genus from which endosiphuncular blades have been recorded.

The species name refers to the endosiphuncular blades.

Occurrence.—The holotype came from locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Family **ENDOCERATIDAE** Hyatt, 1883

Genus **CYRTENDOCERAS** Patrunky, 1926

Type species.—Endoceras (Cyrtocerina) hircus Holm, 1895.

The generic term *Cyrtendoceras* was first used by Remelé in 1886 when he exhibited a cephalopod at a scientific meeting, the report of which appeared in the same year (Remelé, 1886). The name was proposed for a gently cyrtoconic shell with a large, marginal, endogastrically situated siphuncle, and holochoanitic septal necks.[3] Remelé cannot be said to have validly established the genus *Cyrtendoceras,* since he gave no specific name to the specimen.

In 1892 Holm described two species, from the Ordovician of Sweden and Estonia respectively, as *Endoceras (Cyrtocerina) hircus* and *Endoceras (Cyrtocerina) schmidti.* He stated that they were congeneric with the undescribed species represented by the specimen on which Remelé had based his genus *Cyrtendoceras.* Since, however, Holm rejected *Cyrtendoceras,* which he regarded as synonymous with *Cyrtocerina* Billings, it cannot be claimed that he gave validity to the generic name.

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[3] An English translation of Remelé's brief article was given by Foerste, 1932.

In 1906 Ruedemann described a new species under the name of *Cyrtendoceras? priscum.* This cannot affect the validity of *Cyrtendoceras,* since his species was only doubtfully referred to that genus.

As far as we have been able to ascertain, the first person to use *Cyrtendoceras* without reservation and in connection with a valid specific name was Patrunky. In a little known publication (1926), he recorded the presence of "*Cyrtendoceras hircus* Holm" in Ordovician limestones from the Pleistocene drift of northern Germany. Under this name he identified cyrtoconic endoceroids with large marginal siphuncles and endocones. He stated clearly that for such forms the name *Cyrtendoceras,* which he credited to Remelé, was preferred. Patrunky thus gave validity to the genus, and since "*Cyrtendoceras hircus* Holm" is the only species mentioned, this becomes the type species by monotypy.

Foerste (1932) was the first to restudy the specimen for which Remelé coined the name *Cyrtendoceras.* He made this the type of a new species, *C. remelei,* but his proposal to regard this as the type species of *Cyrtendoceras* cannot be accepted.

Fortunately, this confusion about authors and type species raises no major taxonomic problem, because all authors agree to regard *C.hircus, C. schmidti, and C.remelei* as congeneric. A fourth specimen, from the Kunda formation of Estonia, described in Foerste's publication (1932) under the name of *C.estoniense,* may belong to our new genus *Campendoceras.*

The generic diagnosis of *Cyrtendoceras,* based on the type species, as as follows:

Cyrtoconic, endogastric, slightly compressed conchs, with marked growth lines or wrinkles describing lateral saddles and ventral and dorsal lobes; siphuncle large, marginal; septal necks holochoanitic; endocones present.

Hyatt (1900, p. 515) proposed the family Cyrtendoceratidae for the single genus *Cyrtendoceras.* The family was later extended to include any type of endogastric curved conch with a large siphuncle. Thus Foerste (1925) added *Levisoceras, Clarkoceras,* and *Quebecoceras,* and Kobayashi (1937) added *Cyrtovaginoceras.* In 1943 Ulrich, Foerste and Miller discussed the family and the type genus at some length, but based their interpretation of the latter on the supposed type species, *Cyrtendoceras remelei* Foerste, the siphuncular structure of which is not known. In addition, 13 other genera were included in the family. However, almost all of these seem to have short septal necks and complex connecting rings and were correctly placed in the Ellesmeroceratidae by Flower and Kummel (1950). They are not closely related to *Cyrtendoceras*. As has been shown, the latter is a true endoceratid, and since we place little taxonomic value on the curvature of the conch, we do not propose to maintain the family Cyrtendoceratidae. In this we follow Flower and Kummel, who listed the genus among the Endoceratidae.

Cyrtendoceras carnegiei Teichert and Glenister, n. sp. Pl. 8, figs. 6-9; text fig. 12

Description of holotype (No. 351, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 8, figs. 7-9).—The holotype is part of the phragmocone of a rapidly expanding, weakly curved, endogastric cyrtocone. It has a length of 34 mm. and is compressed in cross-section. At the posterior end of the specimen the dorso-ventral and lateral diameters are 28 mm. and 26 mm. respectively, while the corresponding diameters at the anterior end of the specimen are 42 mm. and 39 mm. The siphuncle is large and marginal. It has a dorso-ventral diameter of 15 mm. at the posterior end of the specimen and a corresponding diameter of 16 mm. at the an-

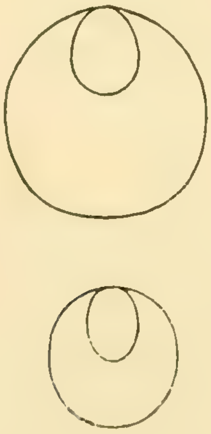

Fig. 12. Anterior and posterior cross-sections of the holotype of *Cyrtendoceras carnegiei.*

terior end. Ten camerae occupy a distance equal to the dorsoventral shell diameter.

The suture consists of a shallow but narrowly rounded lobe across the venter, followed by a rounded saddle across the flanks and a shallow lobe across dorsum. Ectosiphuncular sutures are well developed.

The septal necks are holochoanitic, reaching posteriorly almost exactly to the preceding septum. They are straight and do not turn appreciably inwards at their distal ends. The connecting rings are composed of two layers, a thick outer layer and a regularly thin inner layer. There is a concentration of dense material near the anterior extremity of the thick outer layer. A thin endocone layer is present.

A cylindrical tube, almost centrally situated, occurs in the posterior part of the siphuncle of the holotype. It is considered that this tube has been introduced during fossilization.

Description of paratype (No. 352, Bureau of Mineral Resouces, Geology and Geophysics, Canberra; Pl. 8, fig. 6).—The paratype is a much weathered specimen with a well-preserved siphuncle. The septal necks are holochoanitic. They are conical rather than tubular, so that a considerable lateral gap is left between the posterior tip of each septal neck and the anterior extremity of the neck which precedes it. The connecting rings consist of three components, arranged in two layers. The inner layer is thin and composed of dense material. It originates at the tip of the septal neck and extends posteriorly, as a layer of uniform thickness, to the tip of the preceding septal neck. The outer layer is much thicker and consists of two components. The anterior component is finely crystalline and in some segments is finely laminated, while the larger posterior component is made up of coarsely crystalline material. Endocones are well developed.

This species is named in honour of D. W. Carnegie, who in 1896-1897 explored the eastern margin of the Desert Basin.

Comparisons.—*Cyrtendoceras carnegiei* differs from *Cyrtendoceras hircus* Holm, the type species of the genus, in having straight septal necks and in the absence of wrinkles on the shell surface. The Western Australian species of *Cyrtendoceras* is the only one known to possess a dorsal and ventral lobe with intervening saddles across the flanks. *Cyrtendoceras schmidti* (Holm) and *Cyrtendoceras* *remelei* Foerste have siphuncles which are slightly removed from the ventral wall.

Occurrence.—All the type material came from locality NH 145, Emanuel limestone, Emanuel Creek, Kimberly Division, Western Australia.

Genus **Lobendoceras** Teichert and Glenister, n.gen.

Type species.—Lobendoceras emanuelense Teichert and Glenister, n. sp.

Description.—Orthoconic longicones with smooth shell, circular cross-section, and large marginal siphuncle; conchs moderately expanded anteriorly, camerae short. A broad deep lobe occurs in the ventral suture. Septal necks typically subholochoanitic but may become holochoanitic; connecting rings thick, endocones probably developed.

Affinities.—Lobendoceras is closely allied to *Endoceras,* from which it differs in the possession of a ventral lobe and subholochoanitic rather than holochoanitic septal necks. *Catoraphiceras* differs in having well-developed annulations, and *Thylacoceras* has a much smaller siphuncle.

Lobendoceras emanuelense Teichert and Glenister, n.sp. Pl. 9, figs. 1-7

Description of holotype (No. 346, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 9, figs. 1-4).—The holotype is part of a closely chambered orthoconic phragmocone with a length of 77.4 mm. It is circular in cross-section and expands from a diameter of 19.2 mm. at the posterior end of the specimen to 29.1 mm. at the anterior end. The siphuncle is large and marginal. It is depressed in cross-section due to a ventral flattening. The lateral diameter of the siphuncle is 9.2 mm. at the posterior end of the specimen and 14.0 mm. at the anterior end. Thirty-eight mm. from the posterior end of the specimen the lateral and dorso-ventral diameters of the siphuncle are 10.9 and 9.6 mm. respectively. Ten camerae occupy a distance equal to the shell diameter, and the lateral diameter of the siphuncle is equal to the height of 4.5 camerae.

A broadly rounded ventral lobe occurs in the suture. This lobe has a width slightly less than the lateral diameter of the siphuncle and a depth equal to the length of 1.5 camerae. The ventral lobe is bordered by a pair of low saddles across the flanks and a shallow lobe across the dorsum.

The septal necks are somewhat variable in length. Most of them are subholochoanitic, but several near the posterior end of the holotype are holochoanitic. The distal ends of the septal necks are deflected towards the centre of the siphuncle, so that even when the necks are holochoanitic there is a gap between the distal end of each neck and the proximal end of the preceding one. Connecting rings are thick and apparently uniform in composition. A thin recrystallized interior lining of the posterior end of the siphuncle is interpreted as representing recrystallized endocones. A narrow tube is present in the posterior end of the siphuncle. Similar structures have not been reported from endoceroid siphuncles, and it is thought that the tube was introduced when the rest of the siphuncle was filled with matrix.

Description of paratype (No. 347, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 9, figs. 5-7).—The paratype represents the ventral third of a well-preserved phragmocone. It has a length of 59.2 mm. A lateral section through the siphuncle shows subholochoanitic septal necks, thick connecting rings, and recrystallized endocones. The characteristic deep ventral lobe is well exposed. Most of the shell is preserved; it is smooth.

The species takes its name from the Emanuel limestone.

Occurrence.—Both the holotype and the paratype came from locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **Campendoceras** Teichert and Glenister, n.gen.

Type species.—Campendoceras gracile Teichert and Glenister, n.sp.

Description.—Slightly cyrtoconic, slender, endogastric, longicones with annulate shell, circular cross-section, and large marginal siphuncle; camerae long, sutures straight, septal necks subholochoanitic; endocones present. The generic name is derived from a combination of *Endoceras* and the Greek word for bend.

Affinities.—The only other curved genus of Endoceratidae is *Cyrtendoceras* which differs in being larger and more strongly curved and in having a wrinkled rather than annulate shell.

Campendoceras gracile Teichert and Glenister, n.sp. Pl. 1, figs. 10-11

Description of holotype (No. 371, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—This specimen is a gently curved endogastric longicone with a length of 41 mm. The cross-section of the conch is approximately circular, the diameter of the shell increasing from 2.5 mm. at the posterior end of the specimen to 7.5 mm. at the anterior end. The siphuncle is marginal in position and has a maximum diameter of 3.5 mm. at the anterior end.

Numerous prominent annulations appear on the internal mould. They are directly transverse. Four occur in a distance equal to the shell diameter. The sutures are parallel to the annulations. Five camerae together have a length equal to the diameter of the shell.

The septal necks are not well preserved but appear to be subholochoanitic. The interior of the siphuncle is filled with coarsely crystalline calcite which represents recrystallized endocones. Part of the conical space inside the last endocone is visible near the anterior end of the siphuncle and is now filled with matrix. This last endocone is circular in cross-section and is situated near the middle of the siphuncle.

Comparisons.—The only other known cyrtoconic, distinctly annulate endoceroid, is a species described by Foerste (1932) as *Cyrtendoceras estoniense,* from the Vaginatum limestone (Kunda formation, B3) of Estonia. This species is much larger than *Campendoceras gracile*. In addition to distinct though weak annulations, it has fine transverse striae on the shell. Since the holotypes of the two species represent different portions of the phragmocone, it is difficult to compare them in detail. However, they appear to be closely related and seem to be of similar age. They are, therefore, most probably congeneric.

Occurrence.—Locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Endoceratidae, gen. et sp. ind. Pl. 8, fig. 2-5

1952. Cf. *Meniscoceras* Teichert and Glenister, Jour. Paleont., vol. 26, p. 773.

Two specifically identical fragmentary siphuncles do not seem to belong to any previously described genus. The morphological information they provide is far from complete, and their structures are not fully understood. However, both specimens are described below, since they may prove valuable in stratigraphic correlation. These specimens were previously compared with *Meniscoceras* in a brief survey of the Price's Creek fauna (Teichert and Glenister, 1952).

Description of specimen No. 342 (Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 8, figs. 2-3).—The specimen is a straight, depressed, slowly expanding fragment of a siphuncle, 57.7 mm. in length. At the posterior end of the specimen the lateral diameter is 13.8 mm., while at the anterior end the lateral and dorsoventral diameters are 17.0 mm. and 13.0 mm. respectively. The dorsal surface is evenly rounded, while the ventral surface is almost flat, being gently convex. Weakly developed annulations are present in the anterior half of the specimen. They are interpreted as the lines at which holochoanitic septal necks joined their respective septa. The annulations slope anteriorly from the dorsum to the venter. The distance between five successive annulations is equal to the lateral siphuncular diameter.

The siphuncular deposits consist of three concentric organic layers surrounding a central tube which is filled with matrix. The central tube is crescent-shaped in cross-section. The outermost layer of the siphuncular deposits is fairly uniform in thickness but is thickened on the ventro-lateral flanks. At the anterior end of the specimen, the average thickness of this layer is 1 mm., but the thickness increases to 2 mm. ventro-laterally. Inside this outermost layer lies a more irregular deposit. Dorsally and laterally it has an average thickness of .5 mm. but is inflated ventrally to a thickness of over 3 mm. A superficially similar, wedge-shaped structure occurring in *Manchuroceras steanei* was given the name of "endosiphowedge" by Teichert (1947), but "endosiphuncular wedge" is now preferred. Study of the holotype of *Manchuroceras steanei* shows that the two structures are not closely similar, since the endosiphuncular wedge of *Manchuroceras* is a discrete deposit formed inside the endocones and confined to the ventral side of the siphuncle. On the inside of this second layer lies a further organic layer with a uniform thickness of 1 mm. As a result of the ventral thickening of the middle layer, the inner layer is crescentic in cross-section, being convex dorsally and laterally and flatly concave ventrally. The endosiphuncular cone is also crescentic in cross-section. It is filled with matrix. The three layers are interpreted as three discrete series of recrystallized endocones.

Description of specimen No. 343 (Bureau of Mineral Resourses, Geology and Geophysics, Canberra; Pl. 8, figs. 4-5).—The ventral part of the shell wall and the septa, together with the siphuncle, are preserved in this specimen. Siphuncular structures are almost obliterated by recrystallization. The ventral surface of the siphuncle appears to be in contact with the shell wall. The specimen has a length of 44 mm. At the posterior end the lateral and dorso-ventral siphuncular diameters are 7.0 mm. and 7.5 mm. respectively, while the corresponding diameters at the anterior end of the specimen are 13.6 mm. and 11.0 mm. The siphuncle is oval in cross-section, the dorsal surface being rounded and the ventral surface almost flat. The shell diameter is estimated as 20 mm. Four and a half camerae occupy a distance equal to the lateral diameter of the siphuncle.

Comparisons.—The specimens described above are superficially similar to species of *Meniscoceras* Flower (1941). They differ in having no trace of endosiphuncular blades and in the possession of three discrete endocone layers.

Occurrence.—Specimen No. 342 is from locality NH 142, and specimen No. 343 from locality NH 141, Gap Creek dolomite, Emanuel Creek, Kimberley Division, Western Australia.

Order **BASSLEROCERATIDA**

This order was established by Flower (in Flower and Kummel, 1950) for compressed exogastric cyrtocones with tubular ventral siphuncle. All genera referred to the Bassleroceratida are of Ordovician age. As proposed, it contained only two families, the Bassleroceratidae and the Graciloceratidae. Flower and Kummel state the Bassleroceratidae gave rise to the coiled Tarphyceratida, and it seems to us that they could well be included in that order, representing an early cyrtoconic stock from which the Tarphyceratidae arose through *Aphetoceras* or some similar openly coiled form. We are maintaining the order, because its review would necessitate reconsideration of the Graciloceratidae, a task for which we are not prepared.

Family **BASSLEROCERATIDAE** Ulrich, Foerste, Miller and Unklesbay, 1944

This family was proposed for slender exogastric longicones with compressed siphuncle, orthochoanitic septal necks, and constricted siphuncular segments. The suture consists of prominent dorsal and ventral saddles, separated by lateral lobes. In the same publication, the family Rudolfoceratidae was proposed, to include forms similar to the Bassleroceratidae but differing in the possession of annulations.

The discovery of an annulate species of *Bassleroceras,* described below as *Bassleroceras annulatum,* confirms the present authors' belief that annulations are of subordinate taxonomic value. Some of the genera included by Ulrich, Foerste, Miller and Unklesbay in the Rudolfoceratidae may belong in the Bassleroceratidae. Others such as *Ectoycycloceras* probably belong in the Protocycloceratidae.

Genus **BASSLEROCERAS** Ulrich and Foerste, 1936

Bassleroceras annulatum Teichert and Glenister, n.sp. Pl. 1, figs. 17-18

Description of holotype (No. 353, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The holotype is a gently curved exogastric cyrtocone with a length of 32 mm. The body chamber has a length of 7 mm. The conch is compressed and slowly expanding. At the posterior end of the specimen the dorso-ventral and lateral diameters equal 1.6 mm. and 1.3 mm. respectively. At the base of the living chamber the lateral diameter is equal to 4.4 mm. and the dorso-ventral diameter is estimated as 5.3 mm. The apertural margin is straight and transverse and has a lateral diameter of 5.1 mm.

The camerae are short, eight occupying a distance equal to the lateral diameter. The sutures form a pronounced saddle across the venter. It is separated by two deep, rounded, lateral lobes from a low saddle across the dorsum.

The outside of the shell appears to be weakly annulate, but the annulations are merely external swellings of the shell. The inside of the shell (and, therefore, the surface of the internal mould) is smooth. The annulations are strongest across the flanks and slope anteriorly from the dorsal to the ventral side of the conch at an angle of about 80° to the long axis of the conch. Six evenly spaced annulations are present on the living chamber.

The siphuncle is small and is situated close to, but not in contact with, the ventral wall of the conch. At the posterior end of the specimen, the siphuncle has a diameter of .2 mm. It is tubular in outline, and although not well preserved, it appears to consist of short orthochoanitic septal necks joined by thin connecting rings. The siphuncular segments expand slightly between successive septal foramina.

Comparisons.—The Australian species of *Bassleroceras* is much smaller than *Bassleroceras perseus* (Billings), the type species of the genus. *Bassleroceras annulatum* is also more cyrtoconic and is the only annulate species included in the genus. *Bassleroceras acinacellum* (Whitfield) is, however, almost identical with the Australian species, in cross-section, suture, curvature, and rate of expansion.

Occurrence.—Holotype, No. 353 came from locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Order **DISCOSORIDA**

Family **WESTONOCERATIDAE** Teichert, 1933

Genus **APOCRINOCERAS** Teichert and Glenister, n.gen.

Type species.—*Apocrinoceras talboti* Teichert and Glenister, n.sp.

Description.—Longiconic orthocones with circular cross-section and a small siphuncle situated close to the venter; septal necks cyrtochoanitic with short brims, connecting rings thick; sutures sinuous, camerae short; shell almost smooth.

The generic name is derived from the Greek for "select." Selection Homestead is the old name for Christmas Creek Homestead which is situated near Emanuel Creek.

Affinities.—*Apocrinoceras* is best considered as a primitive member of the Westonoceratidae[4]. The thickened connecting rings, typical of that group, are well developed in *Apocrinoceras*, although neither cinguli nor endocones appear in the siphuncle. It is reasonable to assume that this genus occurred at the base of the westonoceratid stock, prior to the point where this group first began to develop cinguli and endocones. *Apocrinoceras* is the oldest known cephalopod with truly cyrtochoanitic septal necks.

Apocrinoceras talboti Teichert and Glenister, n.sp. Pl. 1, figs. 7-9

Description of specimen No. 354 (Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The holotype and only known specimen belonging to this species is a slowly expanding orthocone 27 mm. long. The cross-section is circular, and the specimen expands from a diameter of 9 mm. at the posterior end to 12.5 mm. at the anterior end. Near the posterior end of the specimen, the siphuncle has a dorso-ventral diameter of 1.2 mm., a lateral diameter of .9 mm., and is situated .2 mm. from the ventral shell wall. Eleven camerae together occupy a distance equal to the shell diameter.

The suture is sinuous and directly transverse. A low saddle occurs across the venter and is followed by a pair of shallow lobes across the ventro-lateral area, a pair of low saddles in the dorsolateral area, and a shallow lobe across the dorsum. Both the shell and the septa are unusually thin. Low irregular annulations and numerous fine striations cover the shell. Both are weakly reflected in the internal cast.

A thin section of 4 mm. of the phragmocone has been made in the dorso-ventral mid-plane. The septal necks are cyrtochoanitic

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[4] In 1952 (p. 744) we stated that the original spelling of the type genus of this family was *Westenoceras* (Foerste 1924) and that the change in spelling to *Westonoceras* suggested by Foerste and Teichert (1930) was inadmissible. Dr. A. K. Miller has now called our attention to the fact that, in his original publication, Foerste (1924, p. 196) did in fact use the alternative spelling *Westonoceras*. Even though this appears only once, in the general introduction, it is possible that its use in print in the original publication makes this spelling available, if desirable, in preference to *Westenoceras*, which is the spelling used in the descriptive part of Foerste's paper.

with short brims, and the siphuncular segments are moderately inflated. The connecting rings are thick and complex in structure. They are composed of a thin inner layer and an extremely thick outer layer. In a typical siphuncular segment with a length of 1.05 mm. and a maximum dorso-ventral diameter of 1.3 mm., the siphuncle is constricted at the septal foramen to a diameter of .75 mm., and the connecting ring has a thickness of .2 mm. The septal necks have a length of .15 mm., and bear brims of .5 mm. length.

This species is named in honour of H. W. B. Talbot who, in 1906-1907 made the first geological reconnaissance of the Desert Basin along the Canning Stock Route.

Occurrences.—Locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Order **TARPHYCERATIDA**

Family **TARPHYCERATIDAE** Hyatt, 1894

Genus **APHETOCERAS** Hyatt, 1894

Aphetoceras delectans Teichert and Glenister, n.sp. Pl. 10, figs. 1-7; text fig. 13

Description of holotype (No. 359, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 10, figs. 1-2).—The holotype is a loosely coiled nautilicone with a maximum diameter of 41 mm. One side of the specimen is worn, but the other is well preserved. It appears that little, if any, of the posterior end of the specimen is missing. Slightly more than one and a half whorls are preserved. All but the anterior fifth of the last whorl is chambered. The whorls of the chambered portion of the shell appear to have been in contact, but the living chamber diverges from the rest of the shell. The living chamber has a length of 14 mm., measured along the concave dorsal side.

The whorls are slightly compressed and more narrowly rounded across the venter than across the dorsum. The dorsum tends to be flattened but an impressed zone is not developed. Near the base of the living chamber the whorl has a height of 10.8 mm. and a width of 9.3 mm. The siphuncle has a height of 1.3 mm., a width of 1.0 mm., and its ventral surface is situated 1.7 mm. from the ventral shell wall.

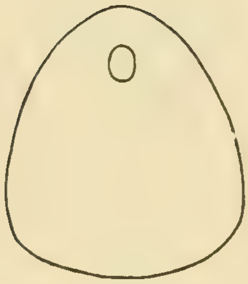

Fig. 13. Cross-section of *Aphetoceras delectans*, × 2½.

Numerous prominent ribs are present on the conch. They are directed transversely across the dorsum but swing posteriorly across the flanks to form a deep but narrow lobe across the venter. The ventral lobe formed by the ribs has a depth equal to the length of almost four camerae. The ribs are V-shaped and pointed in cross-section. They appear as low rounded elevations on the mould of the inside of the shell wall.

Six and a half camerae together occupy a distance equal to the dorso-ventral shell diameter. The sutures are simple. A shallow rounded saddle occurs on both the dorsum and venter, and these are separated on either flank by a shallow rounded lobe. Calcitic deposits do occur in the camerae, but they appear to be of inorganic origin.

The siphuncle does not alter appreciably in relative size or position during ontogenetic development. It occupies a position approximately one-third of the distance between the venter and the centre of the conch. The septal necks are short, straight, and considerably thicker than the septa. Siphuncular segments are slightly expanded. There is a suggestion that the connecting rings are composed of two layers.

Description of paratype (No. 360, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 10, figs. 3-4).—This paratype is a poorly preserved specimen which has been ground and polished in the plane of the siphuncle. It consists of one and a half whorls, one-quarter of a whorl being represented by body chamber. The umbilicus is widely perforate. The last half-whorl diverges from the penultimate whorl, so that the anterior end of the living chamber is separated by a distance of 8 mm. from the adjacent surface of the penultimate whorl. A runzelschicht is well developed.

The connecting rings consist of two discrete components. The inner layer is the thinner of the two and reaches from the tip of one septal neck to the tip of the preceding neck. The outer layer traverses the entire length of the outer surface of the septal necks and reaches posteriorly to the preceding septum. In no case has this outer layer developed along either the anterior or the posterior surface of the septa, suggesting that it is a part of the connecting ring and not a cameral deposit.

Description of paratype (No. 361, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 10, fig. 7).—This specimen is an external mould of an almost complete conch. Like the holotype, it consists of just over one and a half whorls. The anterior half-whorl diverges rapidly from the penultimate whorl, being separated from it by a distance of 14 mm. at the anterior end of the specimen. Well-developed ribs traverse the flanks transversely and swing sharply posteriorly across the venter. Eighteen ribs are present on the last half-whorl.

Description of paratype (No. 362, Bureau of Mineral Resources, Geology and Geophysics, Canberra; Pl. 10, figs. 5-6).—This specimen is a fragment of a living chamber, with a length of 28 mm. It is compressed and oval in cross-section. The dorso-ventral and lateral diameters at the posterior end are 11.5 mm. and 8.5 mm. respectively, while the corresponding diameters at the anterior end are 12.5 mm. and 9.3 mm. The surface is weathered, but the course of the ribs well shown. They are transverse across the dorsum and dorso-lateral area but swing posteriorly across the ventro-lateral area to form deep V-shaped lobes across the venter.

Comparisons.—The ribs of *Aphetoceras delectans* are more strongly developed than those of typical species of *Aphetoceras.* This suggests affinities with the Plectoceratidae, but the Australian species is unlike members of that group in both cross-section and mode of coiling. *Aphetoceras delectans* is easily distinguished from all other species of *Aphetoceras* by its well-developed ribs and double-layered connecting rings.

Occurrence.—Holotype, No. 359 and paratypes, Nos. 361-362 are from locality NL 20 D, and paratype, No. 360 is from locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Aphetoceras desertorum Teichert and Glenister, n.sp. Pl. 10, fig. 8; text fig. 14

Description of holotype (No. 363, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The holotype is part of a loosely coiled gyrocone with an estimated maximum diameter of 40 mm. It has a length of approximately 37 mm. and represents about one-third of a whorl. Half the specimen is represented by living chamber. The posterior 11.9 mm. has been sectioned in the dorso-ventral mid-plane. The whorls expand rapidly, and it is estimated that little more than one complete volution could have developed in the original shell.

The whorls are compressed and oval in cross-section, the dorsum being slightly more narrowly rounded than the venter. The dorso-ventral diameters at the posterior end of the specimen, near the base of the living chamber, and near the anterior end of the specimen are 5.6 mm., 10.1 mm.* and 10.8 mm. respectively; corresponding maximum lateral diameters are 3.2 mm., 6.2 mm., and 7.0 mm.

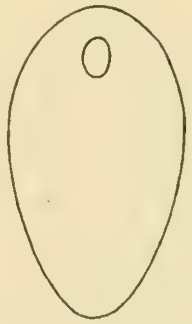

Fig. 14. Cross-section of *Aphetoceras desertorum*, × 4.

The shell is smooth except for the presence of numerous growth lines. They are transversely directed across the dorsum and flanks, but there is some evidence of a sinus across the venter.

Nine camerae together have a length equal to the dorso-ventral shell diameter. The sutures are simple. Shallow rounded saddles are present on the dorsum and the venter. They are separated by shallow rounded lobes across the flanks. The siphuncle is small, compressed, and situated close to the venter. Where the dorso-ventral diameter is 8.8 mm., the siphuncle has a maximum diameter of .8 mm. and is situated .7 mm. from the venter. The siphuncular segment. The length of the camera is 1.0 mm. Septal necks are variable in shape but are always short and orthochoanitic. The septal necks on the dorsal side are generally the longest, averaging about .2 mm. in length, while those on the ventral side are considerably shorter. The connecting rings are thin and structurally simple.

Comparisons.—*Aphetoceras desertorum* is comparable with the group of *Aphetoceras boreale* Hyatt (1894). Both are compressed and oval, and both expand rather more rapidly than typical members of the genus. They probably represent transitional forms between *Aphetoceras* and the rapidly expanding genus *Deltoceras*. The Australian species is distinct in having extremely short camerae and a highly compressed, oval, shell cross-section.

Occurrence.—Locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **AETHOCERAS** Teichert and Glenister, n.gen.

Type species: Aethoceras caurus Teichert and Glenister, n.sp.

Description.—Small, slowly expanding torticonic[5] shells with subcircular cross-section and dextral coiling; siphuncle small, situated close to venter; surface covered with closely spaced transverse apertural flanges.

The generic name is derived from the Greek word for unusual.

Affinities.—Because of its unusual combination of a torticonic shell and apertural flanges the genus is unique not only among Canadian forms, but among early Paleozoic cephalopods generally. It is the oldest torticone known so far and the first coiled form of any kind possessing flanges found in pre-Devonian rocks. Unfortunately, since only one specimen was available for study, it has not been possible to elucidate the structure of the siphuncle. Judging from general shell morphology the genus can be supposed to belong either to the Tarphyceratidae or the Plectoceratidae. Since the former family is much more abundantly represented in Upper Canadian rocks than the latter, we believe that *Aethoceras* may eventually be found to belong to the Tarphyceratidae.

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[5] Nautiloid shells of this type have in the past often been described as "trochoceroid." They are coiled in a three-dimensional spiral like most gastropods. Among ammonoids this type of coiling is often known as helicoidal or "turriliticone." Long ago Hyatt (1900) used the term "torticone" which is simply descriptive and applicable to all groups. There is no reason to perpetuate a multiple terminology for the same feature in one and the same phylum of invertebrates.

Aethoceras caurus Teichert and Glenister, n.sp. Pl. 9, figs. 8-10; text fig. 15

Description of holotype (No. 364, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The holotype is an internal mould of a shell which consists of slightly more than one whorl of a loosely coiled torticone with a maximum diameter of 23 mm. The whorls are almost in contact, but a depressed zone is not developed. One quarter of the last whorl is represented by body chamber. The lateral diameter of the body chamber at its adapertural end is 10 mm., its dorso-ventral diameter 7 to 8 mm. The shell has been removed from one side of the specimen but remains intact on the opposite side. A consideration of the rate of expansion of the whorls indicates that the shell was widely perforate. At the beginning of the last preserved whorl the mid-ventral axis of that whorl lies about 4 mm. off the plane of symmetry of the body chamber at its apertural end, thus affording a measure of the helicoidal coiling of the shell.

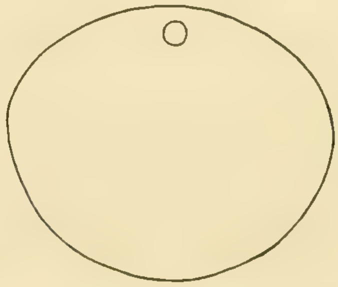

Fig. 15. Cross-section of *Aethoceras caurus*, × 5.

The whorls are slightly depressed and evenly rounded across the dorsum and venter. Where the lateral diameter is 6.3 mm. and the dorso-ventral diameter 5.4 mm., the siphuncle has a diameter of .45 mm. and its ventral margin is situated .35 mm. from the venter.

The ornamentation consists of a remarkable system of flanges. These flanges attain a length of up to 4 mm., although except near their bases they are rarely thicker than .15 mm. Their bases are directed transversely across the flanks but swing posteriorly across the venter to form a broad but deep lobe. The flanges are low across the dorsum, have a maximum length across the flanks, and are probably considerably shorter across the venter. The distal part of the flange is directed anteriorly, forming an angle of approximately 60° with the shell surface. A runzelschicht is well developed.

The suture is almost straight and transverse, but very shallow lobes form on the flanks, and a shallow saddle is formed across the dorsum and the venter.

The species takes its name from the Latin word for northwest wind.

Occurrence.—Locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **ESTONIOCERAS** Noetling, 1883

Estionioceras sp. Pl. 10, fig. 9; text fig. 16

Description of specimen No. 34130 (Department of Geology, University of Western Australia).—Only one specimen belonging to *Estonioceras* is known to the authors. It is a fragmentary specimen consisting of one and a half whorls, one-quarter of a whorl being represented by body chamber. The maximum diameter attained is estimated at 30 mm. The umbilicus is widely perforated. Transverse

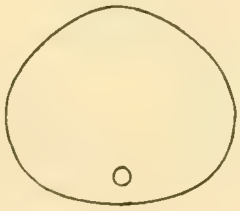

Fig. 16. Cross-section of *Estonioceras* sp., × 2½.

cross-sections show that the whorls are depressed, the venter being flatter than the dorsum. At the base of the body chamber, the dorso-ventral and lateral diameters measure 7.9 mm. and 8.9 mm. respectively. Where the dorso-ventral diameter is 4.1 mm., the lateral diameter measures 4.9 mm., while the siphuncle has a diameter of .4 mm. and is situated .4 mm. from the ventral shell wall. An impressed zone is not developed on the dorsal surface, and the whorls are not in contact. The base of the body chamber is separated from the penultimate whorls by a distance of 1.4 mm., while the anterior end is separated from that whorl by a distance of 2.5 mm.

The suture is transverse and only slightly sinuous. Irregularly spaced indistinct ribs occur. They are directed posteriorly across the flanks to form a shallow rounded lobe across the venter.

Comparisons.—The Western Australian species of *Estonioceras* differs from typical members of this genus in being more loosely coiled and in possessing weaker ornamentation. Both features may, in part, be a function of weathering and distortion. The whorls are in contact, at least in the early growth stages, in typical members of the genus. It is possible that the whorls of *Estonioceras* sp. have been separated during distortion of the specimen. The strength of the ornamentation on *Estonioceras* sp. has been reduced by weathering.

Occurrence.—Locality E 10, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **PYCNOCERAS** Hyatt, 1894

Pycnoceras liratum Teichert and Glenister, n.sp. Pl. 10, figs. 12-15; text fig. 17

Description of holotype (No. 358, Bureau of Mineral Resources, Geology and Geophysics, Canberra).—The holotype and only known representative of the species consists of two-thirds of a well-preserved

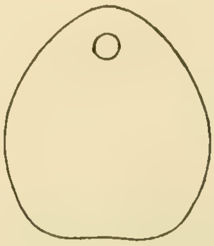

Fig. 17. Cross-section of *Pycnoceras liratum*, × 2½.

subdiscoidal nautilicone. Two and a half volutions are present, about one-sixth of a volution consisting of living chambers. The maximum whorl diameter is 41 mm. The whorls expand slowly, and are in contact throughout, including the living chamber. It is probable that the conch was narrowly perforate.

The living chamber is subquadrate in cross-section, the dorso-ventral and lateral diameters being almost identical. Earlier whorls are slightly compressed, with a flat dorsum showing a tendency towards development of a shallow impressed zone. The siphuncle is situated close to, but not in contact with, the ventral shell wall. Where the dorso-ventral diameter is 9.1 mm. and the lateral diameter 7.9 mm., the siphuncle has a diameter of 1.1 mm. and has its ventral margin situated .8 mm. from the ventral shell wall.

Ornamentation consists of numerous evenly spaced lirae, which are developed in all growth stages. These narrow, sharply crested ridges are directed transversely across the flanks, and swing backwards to form a deep and narrowly rounded sinus across the venter. Twenty lirae are present in a distance of .9 mm., measured along the flanks of the living chamber. The runzelschicht, described in many Palaeozoic ammonoids and noted by the present authors (1952) in *Hardmanoceras lobatum*, and in several other species in this report, is well developed. The suture is essentially straight and transverse, but shallow lateral saddles, separated by dorsal and ventral lobes, are developed in earlier whorls.

Siphuncular segments are gently expanded between successive foramina. The septal necks are short and orthochoanitic. In a typical siphuncular segment with a length of 1.6 mm. and a maximum diameter of 1.2 mm., the diameter of the septal foramen is 1.1 mm., and the septal neck has a length of .2 mm.

Comparisons.—*Pycnoceras liratum* is a typical member of the genus. It may, however, be readily separated from all other described species of *Pycnoceras* by the well-developed lirae.

Occurrence.—The holotype came from locality NL 20 E, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Family **TROCHOLITIDAE** Chapman, 1857

Genus **ARKOCERAS** Ulrich, Foerste, Miller and Furnish, 1942

Arkoceras sp. Pl. 10, figs. 10-11; text fig. 18

A single fragment of a silicified phragmocone was available for study. It is too fragmentary to serve as the type of a new species.

Description of specimen No. 357.—(Bureau of Mineral Resources, Geology and Geophysics, Canberra). The specimen is considered to be part of a loosely coiled nautilicone, with an estimated maximum diameter of 15 mm. It is chambered throughout, has a length of 11 mm., and represents about one-third of a volution.

The whorl is compressed and oval in cross-section, the dorsum being slightly more narrowly rounded than the venter. The dorso-ventral and lateral diameters at the posterior end of specimen measure 2.7 mm. and 2.3 mm. respectively. The corresponding diameters at the anterior end are 4.4 mm. and 3.7 mm. The siphuncle is moderately large, compressed, and situated close to, but not in contact with, the dorsal shell wall. At the anterior end of the specimen the siphuncle has a dorso-ventral diameter of .7 mm., a lateral diameter of .5 mm., and its dorsal margin is situated .2 mm. from the dorsum.

The sutures are simple and represent a direct reflection of the shell cross-section. A shallow dorsal saddle is separated by a pair of shallow rounded lateral lobes from a higher saddle across the venter. The shell is smooth.

Comparisons.—*Arkoceras*, *Cyclolituites*, and *Wichitoceras* are the only members of the Trocholitidae which are not dorsally impressed. The specimen described above has affinities with both *Arko-*

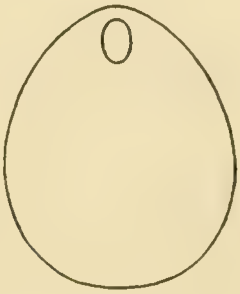

Fig. 18. Cross-section of *Arkoceras sp.*, × 6½.

ceras and *Wichitoceras*, being intermediate in position between these closely allied genera. *Arkoceras exiguum*, the type species of *Arkoceras*, is either round or slightly depressed in cross-section. *Arkoceras* sp., described above, is slightly compressed, and *Wichitoceras compressum*, the type species of *Wichitoceras*, is highly compressed. As a consequence of the cross-section, the sutures of *Arkoceras exiguum* are straight and transverse, whereas *Wichitoceras compressum* exhibits dorsal and ventral saddles separated by lobes across the flanks. Here again *Arkoceras* sp. is intermediate between the two genera. The closer affinities as regards cross-section are, however, with *Arkoceras*.

Occurrence.—Locality NL 17, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

Genus **HARDMANOCERAS** Teichert and Glenister, 1952

Hardmanoceras lobatum Teichert and Glenister, 1952 Pl. 7, figs. 10-11

1952. *Hardmanoceras lobatum* Teichert and Glenister, Jour. Pal., vol. 26, pp. 748-749.

Hardmanoceras lobatum, the type species of that genus, is known from numerous excellently preserved conchs. A well-preserved gerontic specimen which recently came into the authors' collections adds considerably to our knowledge of this species.

Description of hypotype (No. 34128, Department of Geology, University of Western Australia).—This specimen is a discoidal nautilicone consisting of five whorls, one and a quarter of which are body chamber. It has a maximum diameter of 50.5 mm. All the whorls are in contact except for the anterior quarter of a volution. This diverges from the remainder of the conch, so that at the anterior end of the body chamber its dorsal surface is separated by a distance of 2.5 mm. from the penultimate whorl. The whorl cross-section is subrectangular, depressed, and impressed dorsally. No trace of the protoconch can be found, but from a consideration of the rate of size increase of the whorls, it seems probable that the umbilicus was narrowly perforate.

Numerous prominent ribs occur on all whorls. They are directed transversely across the dorso-lateral area but swing posteriorly across the ventro-lateral area to form a deep V-shaped lobe across the venter. They are regularly spaced and even in strength over all but the last half-whorl. There they become progressively weaker, less uniform, and more numerous, until near the aperture they occur only as irregular, ill-defined undulations. A prominent constriction occurs just behind the present aperture, its course paralleling that of the ribs. The present apertural margin is also parallel to the ribs, and a deep hyponomic sinus is thus formed. These features indicate that the anterior end of the shell represents the aperture at the time of death of the animal.

The sutures consist of a shallow rounded lobe across the dorsum and the venter, separated by a low saddle on either flank. The length of the camerae is greatly reduced towards the anterior end of the phragmocone, so that the last ten camerae are only half as long as those situated half a whorl posteriorly from them.

Discussion.—This specimen demonstrates that geronticism in the species is marked by divergence of the living chamber, reduction in strength of the ornamentation, and reduction in length of the chambers.

Occurrence.—Holotype, No. 482 (17735) came from locality NL 20 E, paratype, No. 483 (17736) from locality NL 20 F, and hypotype, No. 34128 from locality E 11, Emanuel limestone, Emanuel Creek, Kimberley Division, Western Australia.

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PLATES

PLATE 1 (14)

Explanation of Plate 1 (14)

Figure Page

1-4. **Kyminoceras forresti** Teichert and Glenister, n. gen., n. sp. 43

1. Thin section of paratype, No. 34121, × 9. 2-4. Holotype, No. 34120, × 1. 2. Ventral. 3. Dorsal. 4. Posterior.

5-6. **Ectocycloceras inflatum** Teichert and Glenister, n. sp. 41

Holotype(No. 370. 5. Lateral, × 1. 6. Ventral, × 1.

7-9. **Apocrinoceras talboti** Teichert and Glenister, n. gen., n. sp. 76

7. Thin section of holotype, No. 354, × 10. 8,9. Holotype, No. 354. 8. Lateral, × 1. 9. Ventral, × 1.

10-11. **Campendoceras gracile** Teichert and Glenister, n. gen., n. sp. 71

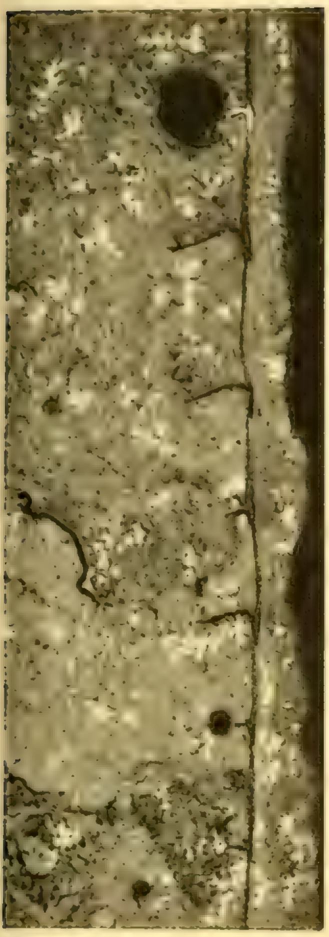
Holotype, No. 371. 10. Lateral, × 1. 11. Ventral, × 1.

12-16. **Diastoloceras perplexum** Teichert and Glenister, n. gen., n. sp. 45

12-16. Holotype, No. 345, × 1. 12. Posterior. 13. Ventral. 14. Lateral. 15-16. Lateral casts of shell.

17-18. **Bassleroceras annulatum** Teichert and Glenister, n. sp. 74

Holotype, No. 353, × 1. 17. Lateral. 18. Ventral.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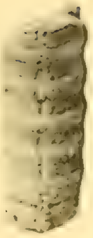
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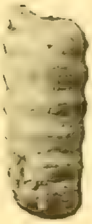
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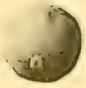
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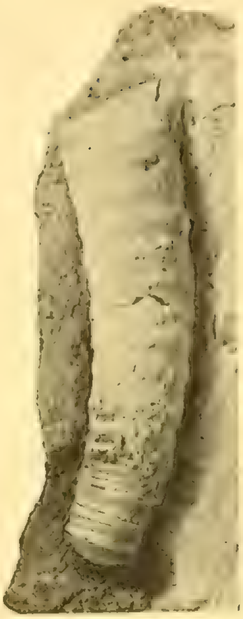
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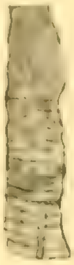
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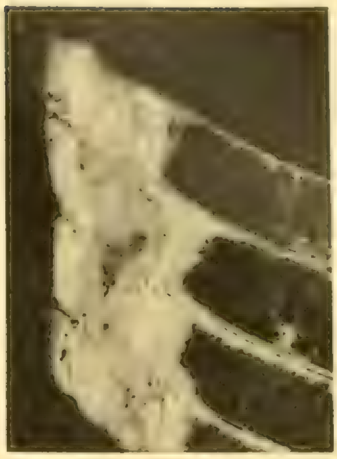
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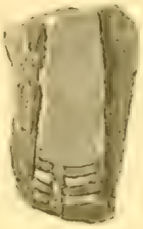
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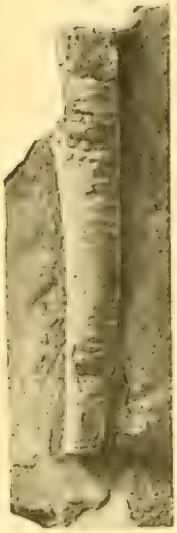
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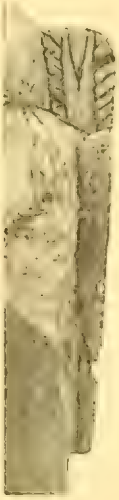
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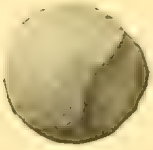
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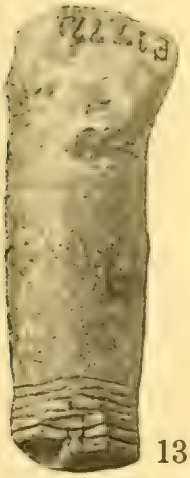
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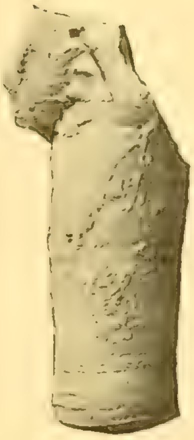
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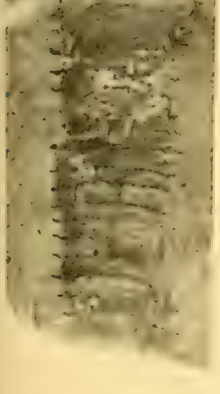
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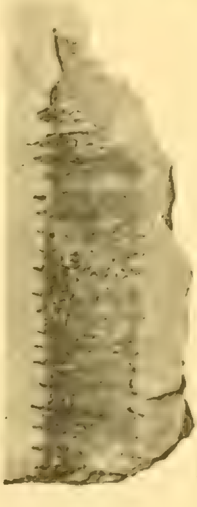
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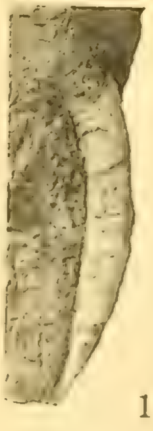
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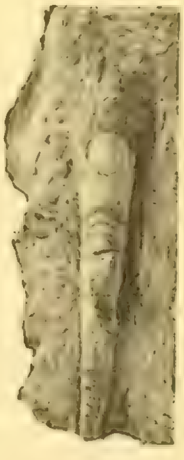
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PLATE 2 (15)

Explanation of Plate 2 (15)

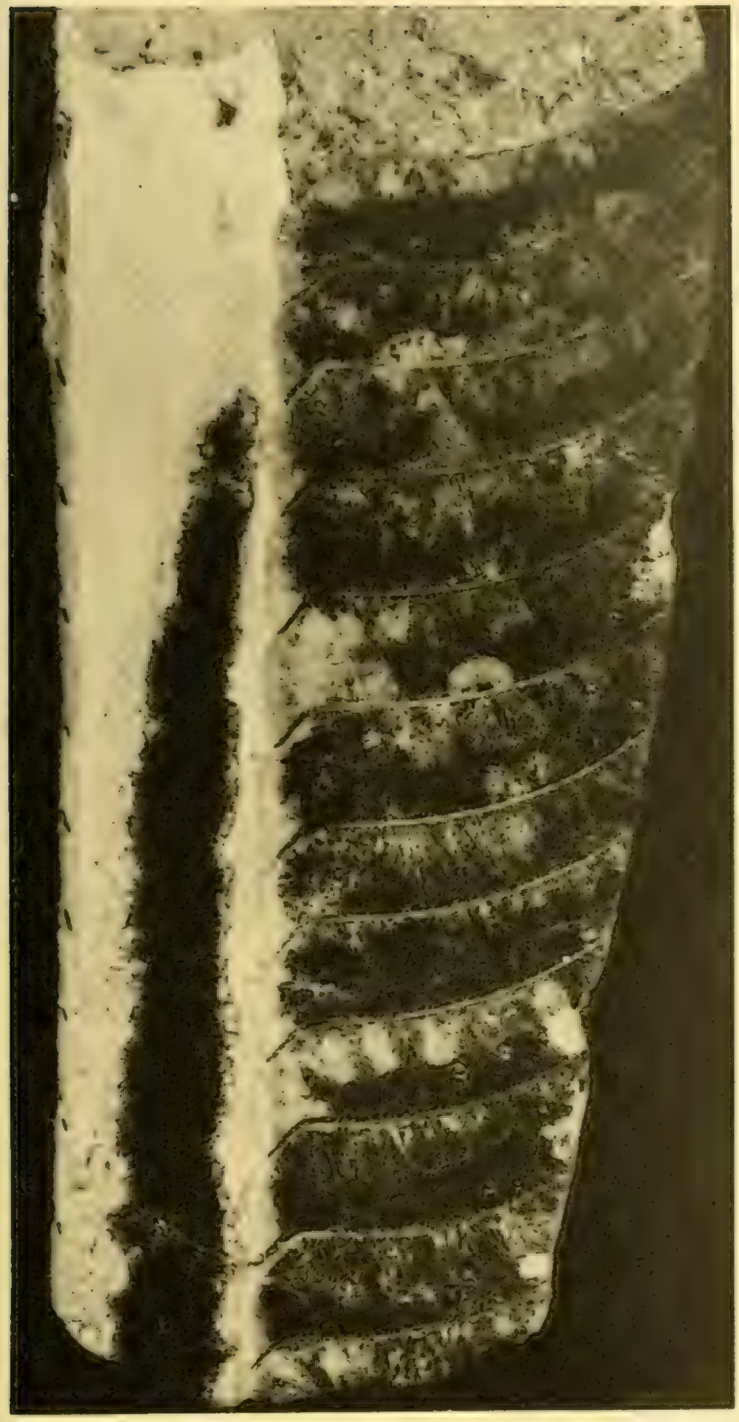
Figure Page

1-4. **Loxochoanella warburtoni** Teichert and Glenister, n. gen. n. sp. 37

Thin section of holotype, No. 34122, × 9. 2. Thin section of paratype, No. 338, × 9. 3. Holotype, No. 34122; ventral, × 1. 4. Thin section of paratype, No. 339, × 9.

5. **Hemichoanella canningi** Teichert and Glenister, n. gen., n. sp. 47

Holotype, No. 334; dorsal, × 1.



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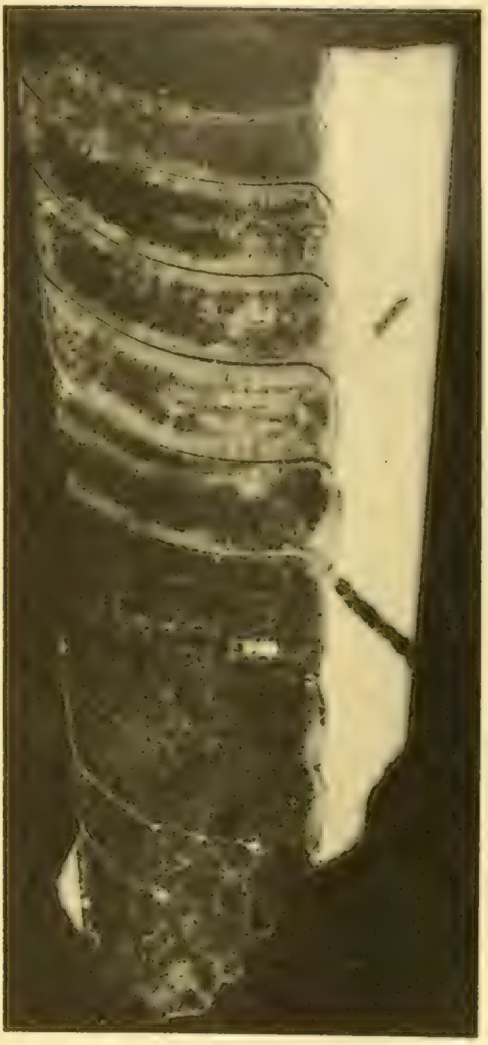

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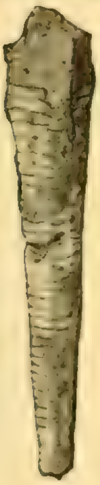

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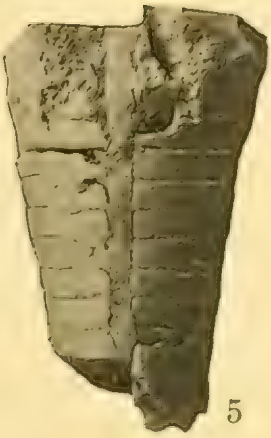

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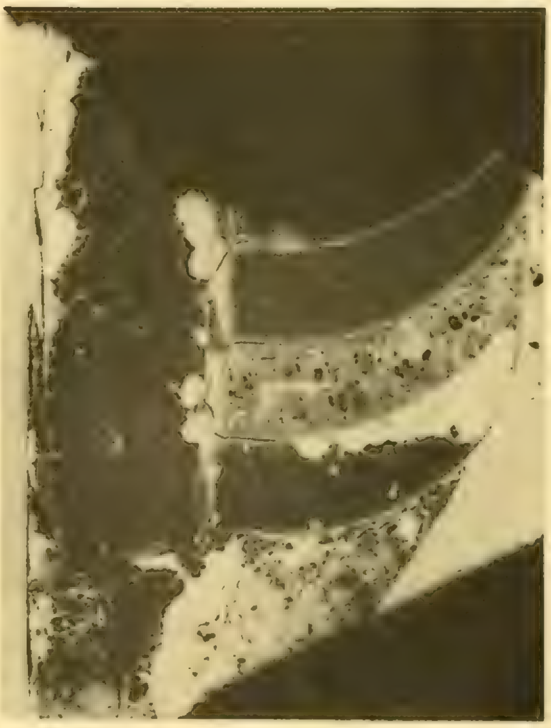

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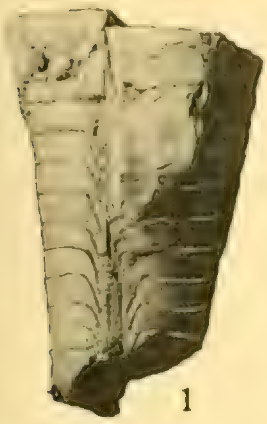
PLATE 3 (16)

Explanation of Plate 3 (16)

Figure		Page
1-4.	**Hemichoanella canningi** Teichert and Glenister, n. gen., n .sp.	47
	Holotype, No. 344. 1. Ventral, × 1. 2. Lateral, × 1. 3. Dorso-ventral section, × 5. 4. Dorso-ventral section, × 1.	
5-13.	**Eothinoceras maitlandi** Teichert and Glenister, n.sp.	49
	5. Hypotype, No. 338A; ventral, × 1. 6. Hypotype, No. 34125; ventral, × 1. 7. Hypotype, No. 34126; ventral, × 1. 8. Hypotype, No. 34124; ventral, × 1. 9. Holotype No. 34123; ventral, × 1. 10. Thin section of paratype, No. 336, ×9. 11, holotype, No. 34123; anterior, × 1. 12. Dorso-ventral section of hypotype, No. 337, × 1. 13. Dorso-ventral section of paratype, No. 335, × 1.	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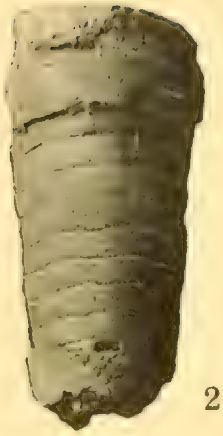
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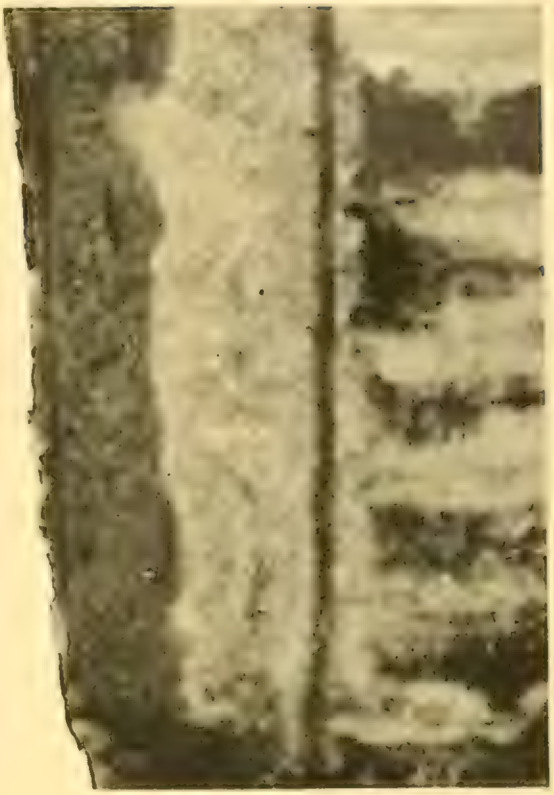
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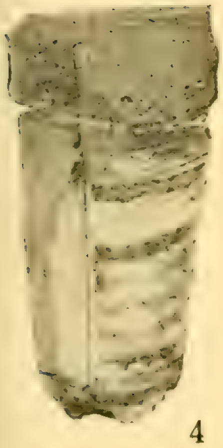
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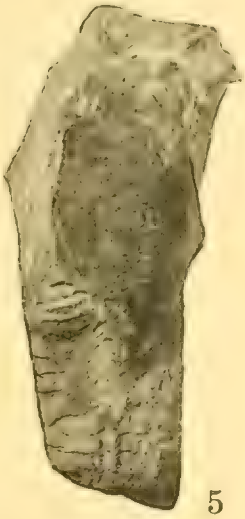
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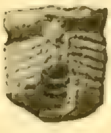
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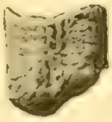
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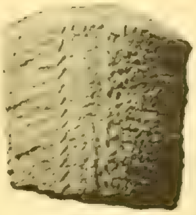
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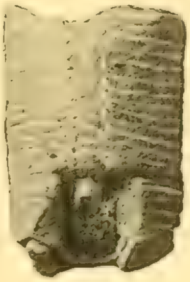
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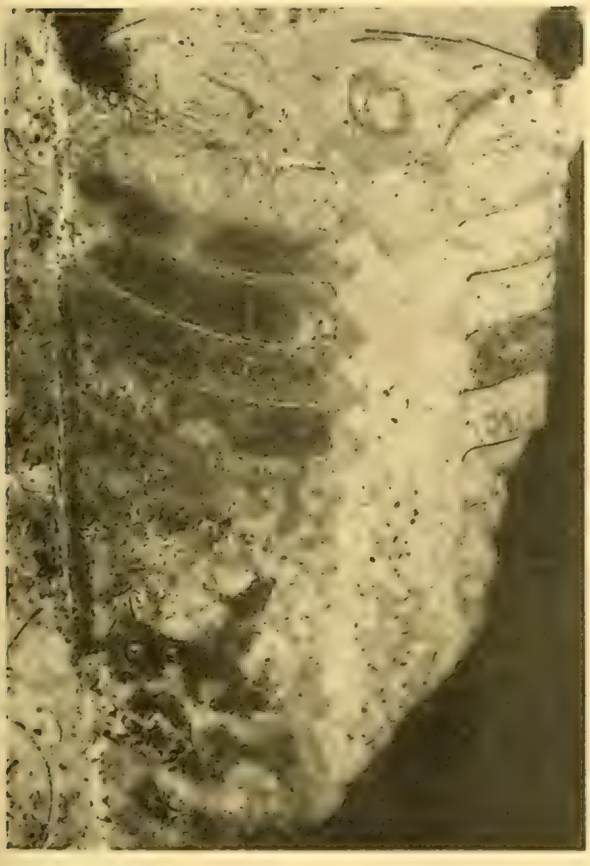
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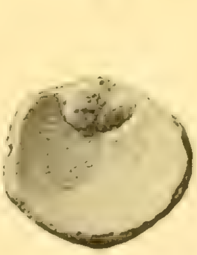
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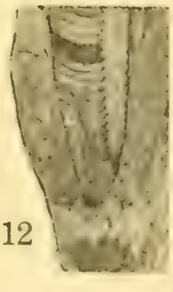
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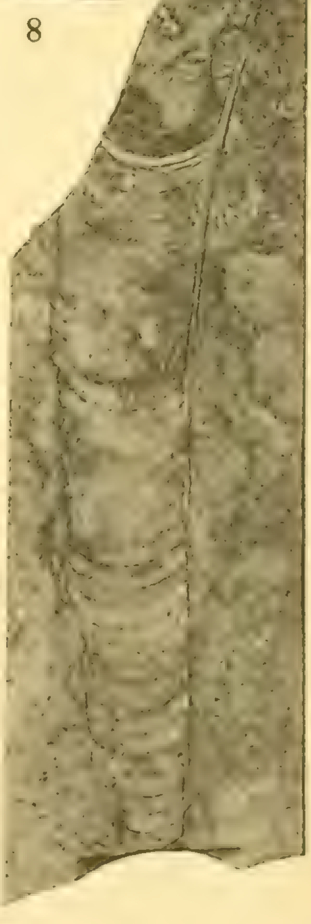
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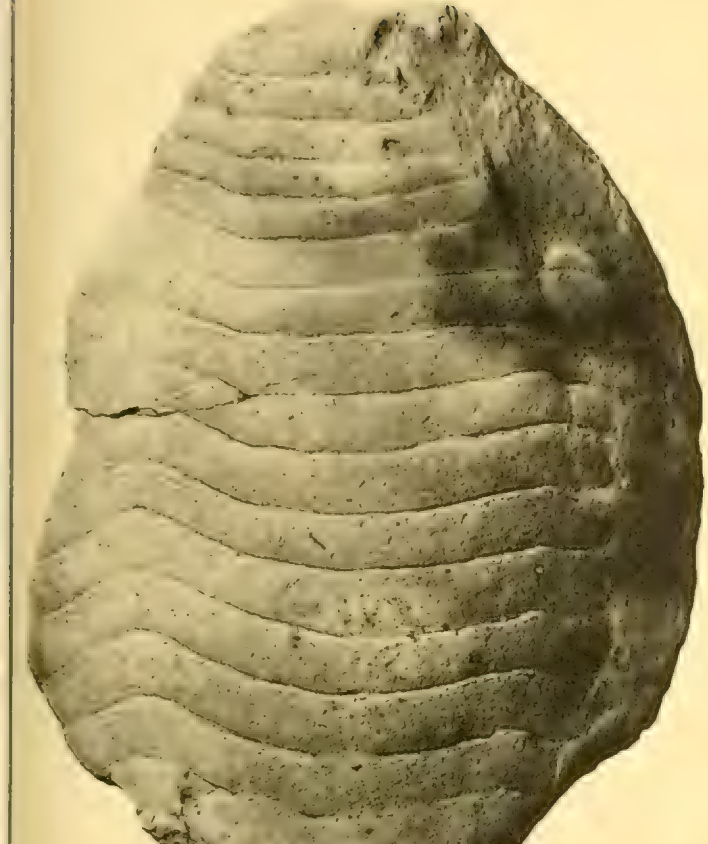
PLATE 4 (17)

Explanation of Plate 4 (17)

Figure		Page
1-4	**Proterocameroceras contrarium** Teichert and Glenister n. sp.	59
	1. Holotype, No. 366; ventral, × 1. 2. Paratype, No. 367, dorso-ventral polished section, × 5. 3. Holotype, No. 366; dorso-ventral polished section, × 1. 4. Holotype, No. 366; ventral, × 1.	



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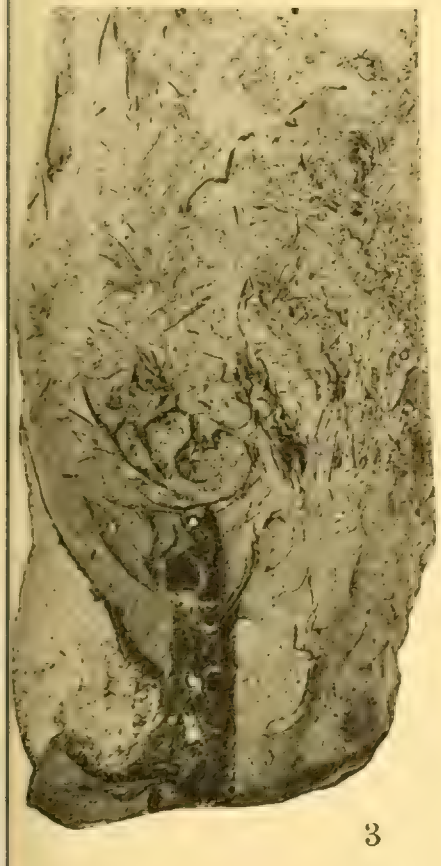

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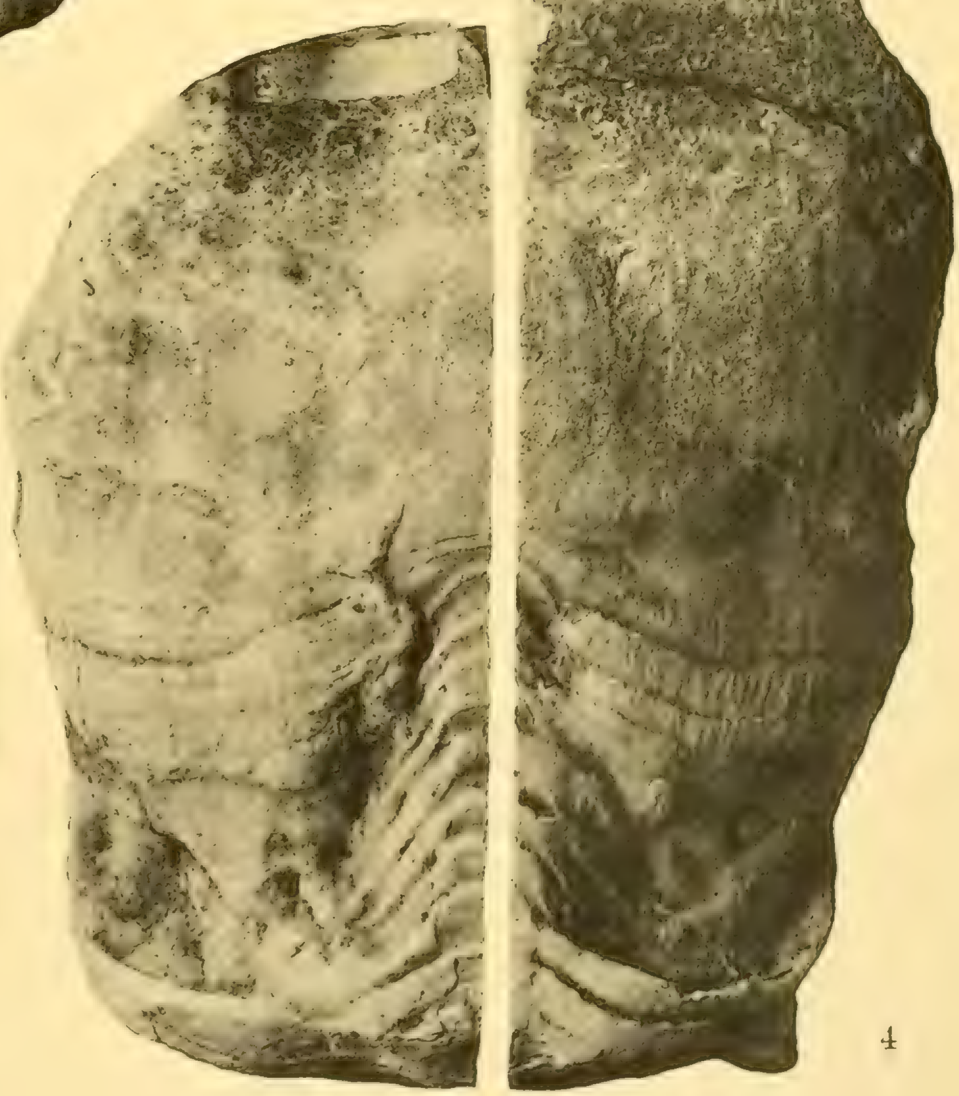

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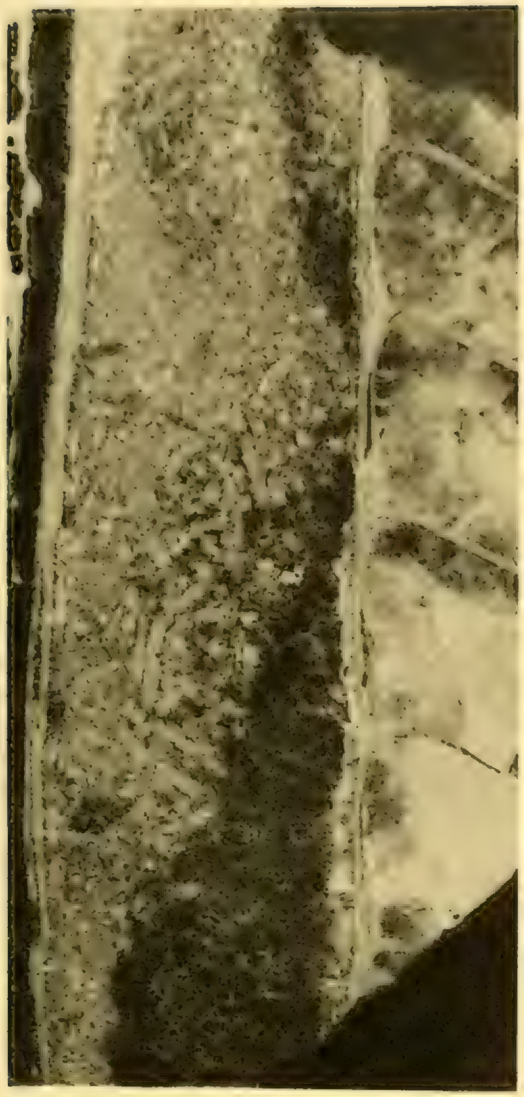
PLATE 5 (18)

Explanation of Plate 5 (18)

Figure		Page
1-5.	**Lebetoceras oepiki** Teichert and Glenister, n. gen., n. sp.	54
	1-2. Holotype, No. 340. 1. Dorso-ventral thin section, × 9. 2. Dorso-ventral polished section, × 1. 3-5. Paratype, No. 341. 3. Ventral, × 1. 4. Lateral, × 1. 5. Dorso-ventral thin section, × 9.	
6-7.	**Notocycloceras yurabiense** Teichert and Glenister, n. gen., n. sp.	56
	Holotype, No. 350, × 1. 6. Anterior. 7. Ventral.	



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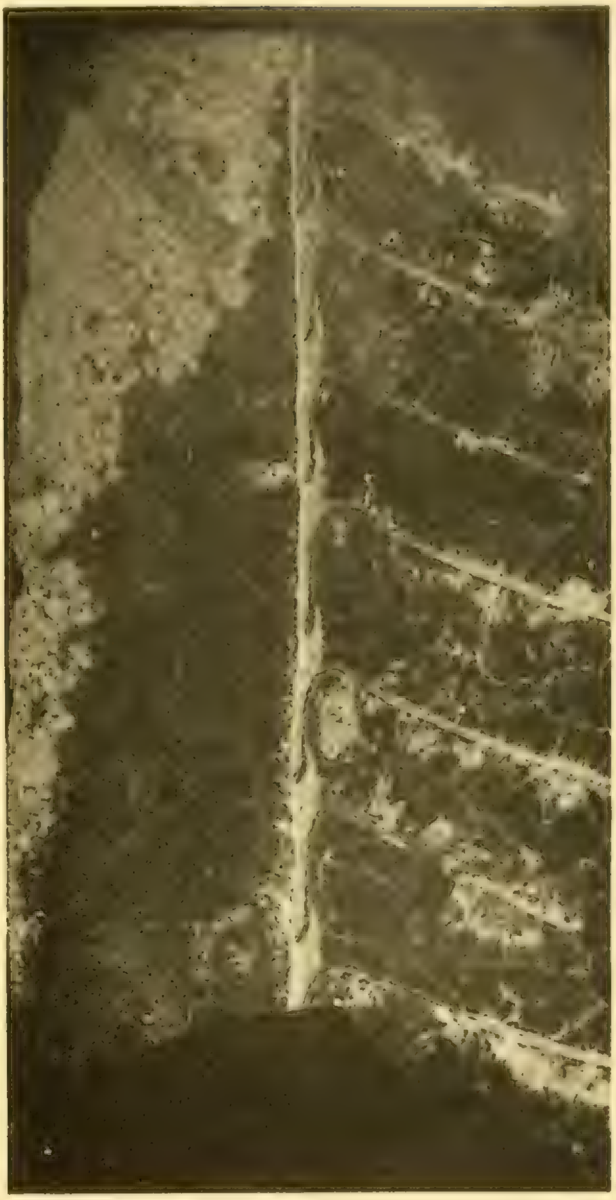

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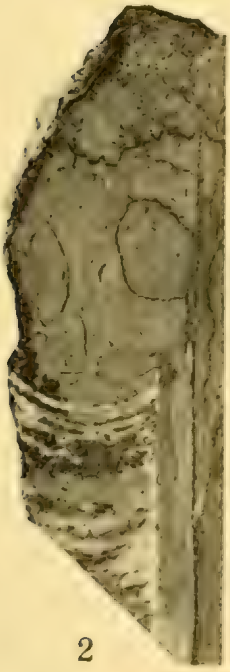

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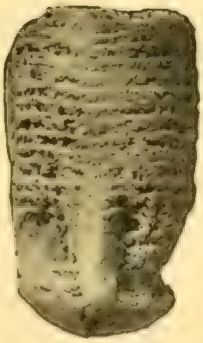

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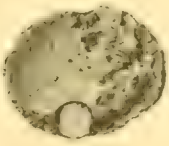

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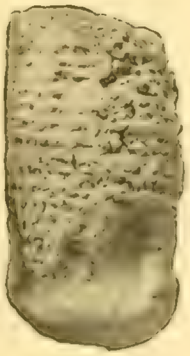

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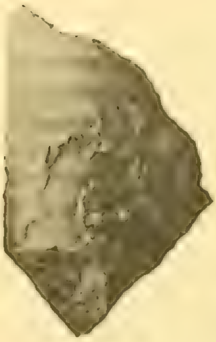

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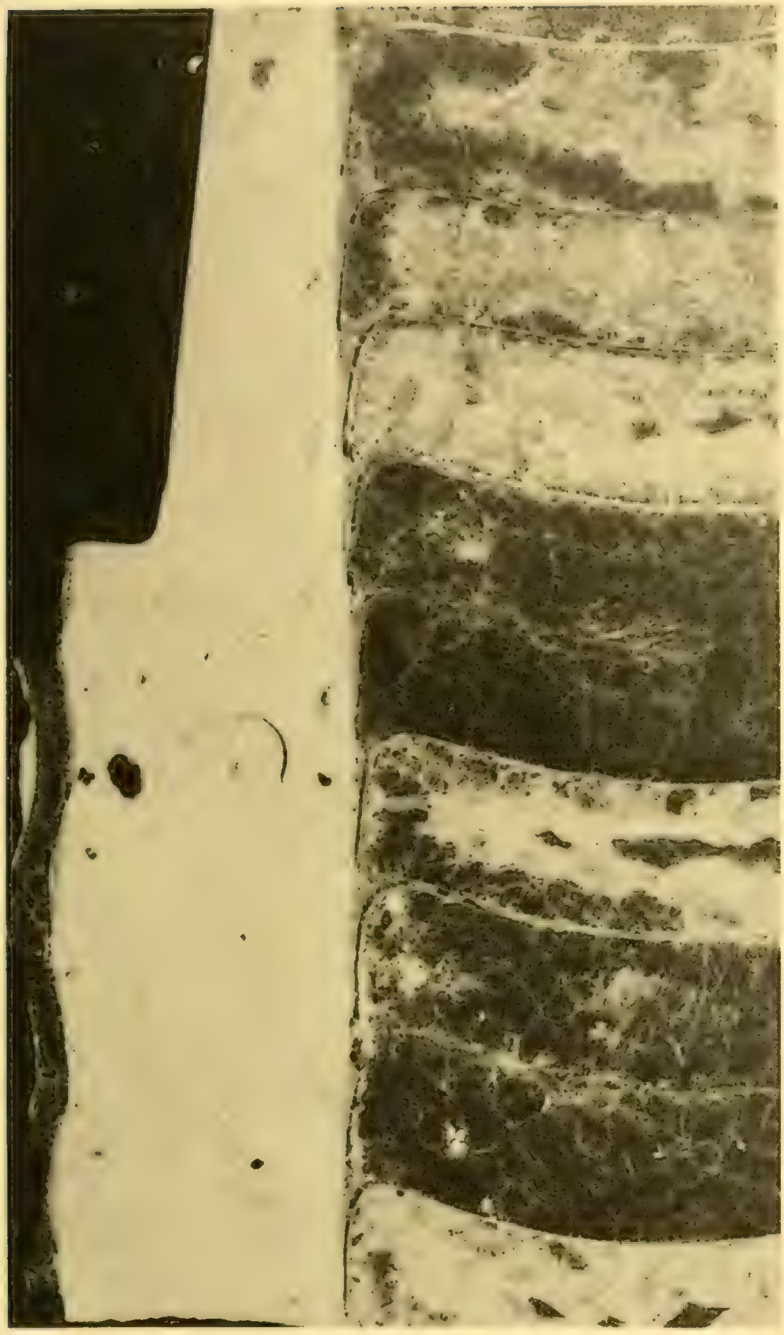
PLATE 6 (19)

Explanation of Plate 6 (19)

Figure		Page
1.	**Notocycloceras yurabiense** Teichert and Glenister, n. gen., n. sp.	56
	Dorso-ventral thin section of holotype, No. 350, × 9.	
2-5.	**Thylacoceras kimberleyense** Teichert and Glenister, 1952	52
	2. Dorso-ventral thin section of hypotype, No. 349, × 9. 3-5. Hypotype, No. 348, × 1; 3. Ventral. 4. Dorsal. 5. Lateral.	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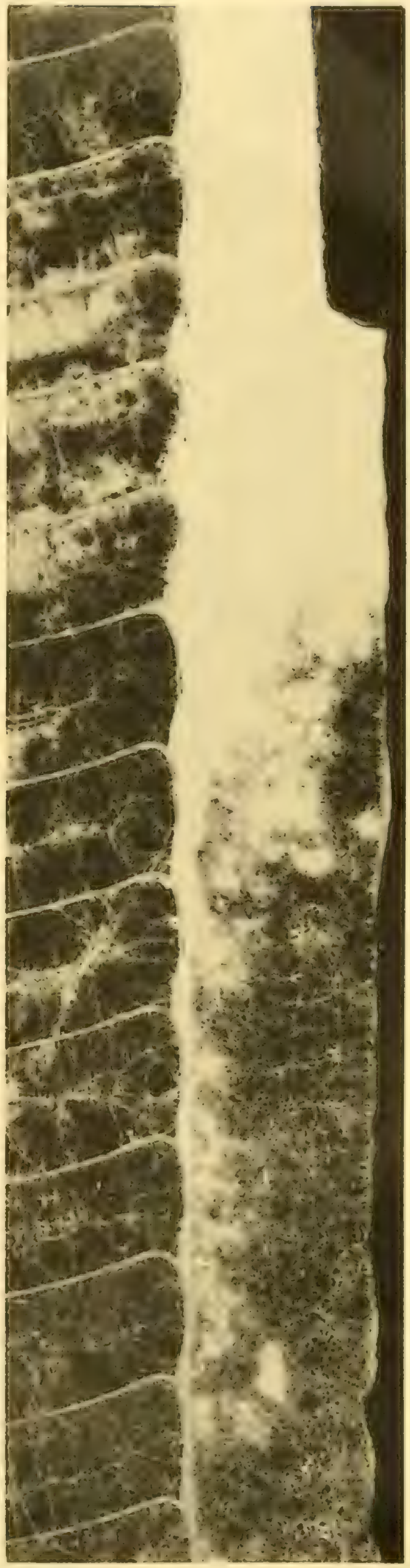
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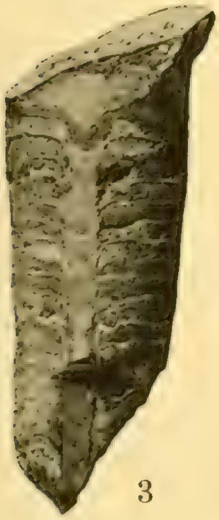
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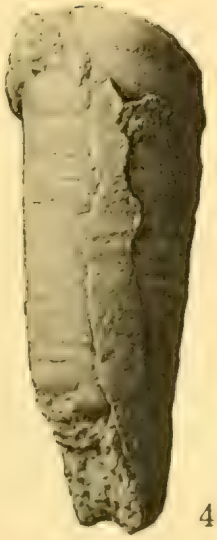
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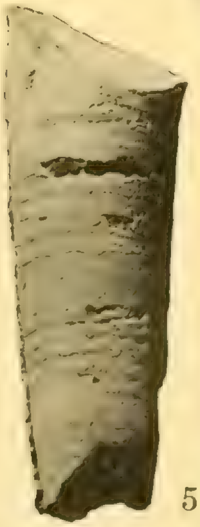
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PLATE 7 (20)

Explanation of Plate 7 (20)

Figure		Page
1-4.	**Ventroloboceras furcillatum** Teichert and Glenister, n. gen. n. sp. Holotype, No. 356. 1. Ventral, × 1. 2. Lateral, × 1. 3. Dorsoventral thin section, × 9. 4. Posterior, × 1.	58
5-7.	**Thylacoceras teretilobatum,** Teichert and Glenister, n.sp. Holotype, No. 34127, × 1. 5. Posterior. 6. Ventral. 7. Lateral.	53
8-9.	**Allopiloceras calamus** Teichert and Glenister, n. sp. Holotype, No. 355, × 1. 8. Lateral; 9. Anterior.	64
10-11.	**Hardmanoceras lobatum** Teichert and Glenister, 1952 Hypotype, No. 34128, × 1. 10. Left. 11. Right.	87

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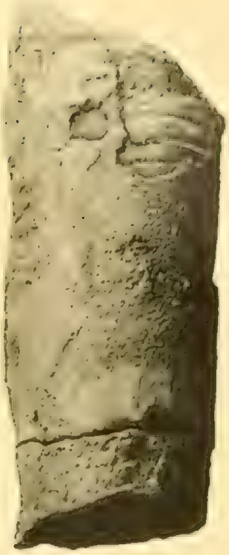
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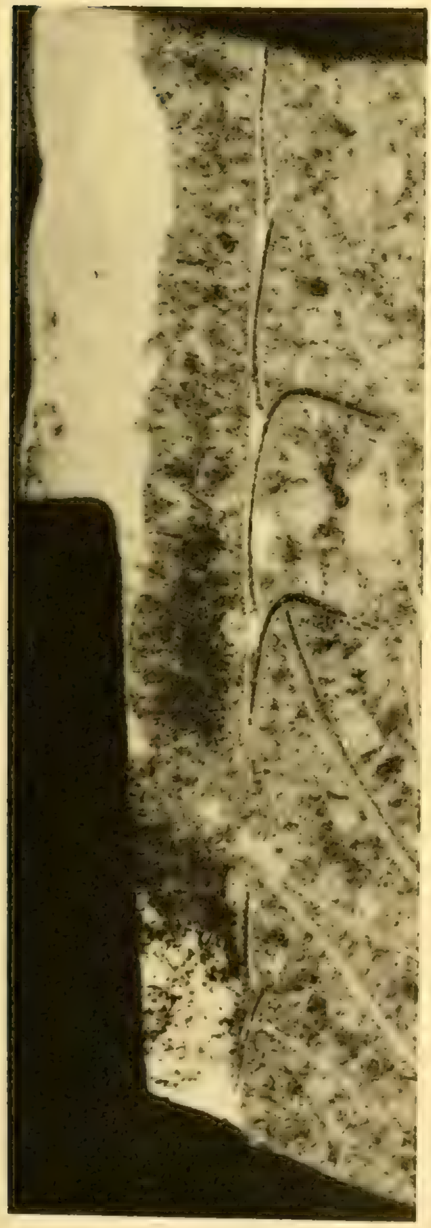

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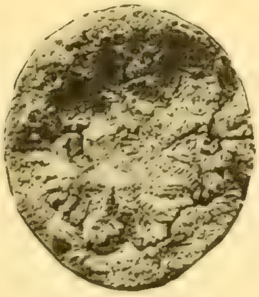
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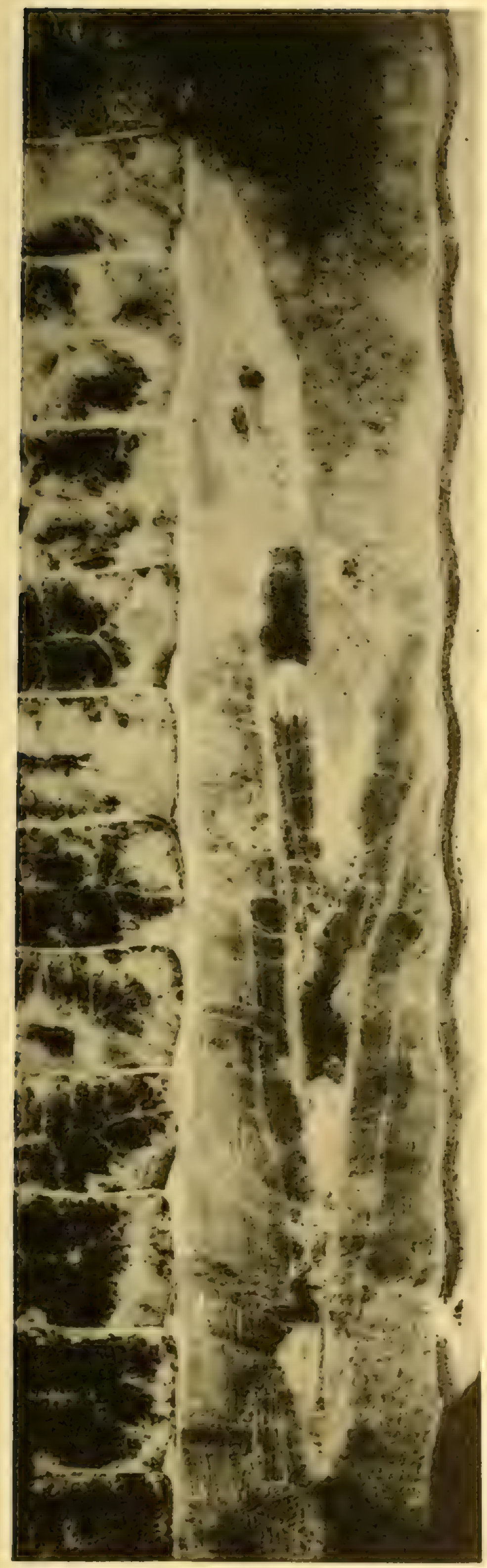
PLATE 8 (21)

Explanation of Plate 8 (21)

Figure		Page
1.	**Anthoceras decorum** Teichert and Glenister, n. gen., n. sp.	63
	Thin section of holotype, No. 34128, × 9.	
2-5.	**Endoceratidae** gen. et sp. ind.	71
	2,3. Hypotype, No. 342, × 1. 2. Dorsal. 3. Anterior. 4,5. Hypotype, No. 343, × 1. 4. Dorsal. 5. Anterior.	
6-9.	**Cyrtendoceras carnegiei** Teichert and Glenister, n. sp.	67
	6. Thin section of paratype, No. 352, × 9. 7-9. Holotype, No. 351, × 1; 7. Anterior. 8. Dorso-ventral polished section. 9. Lateral.	



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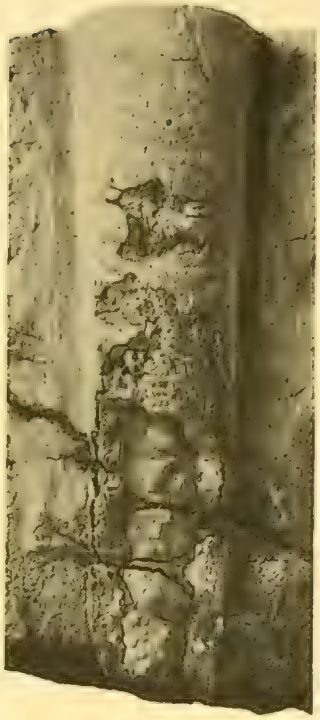

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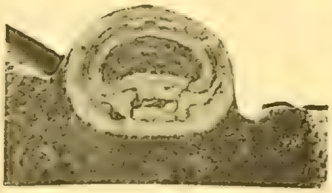

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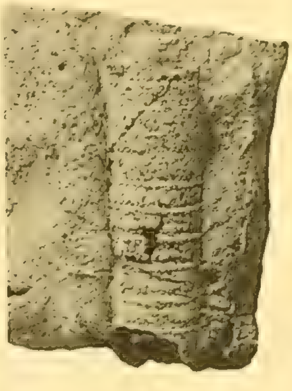

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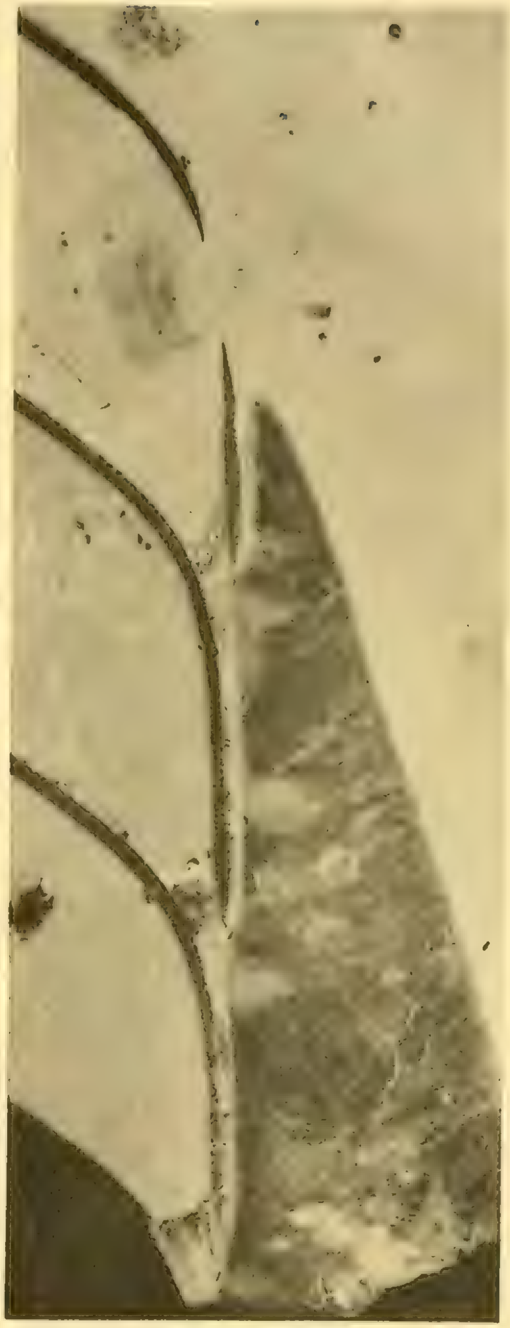

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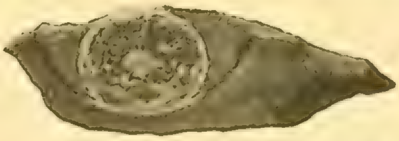

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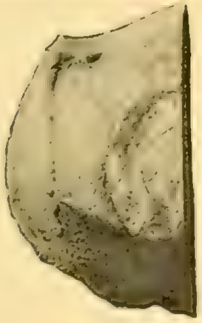

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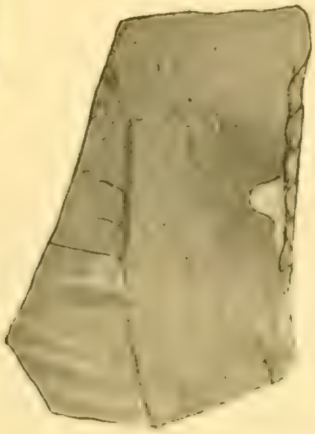

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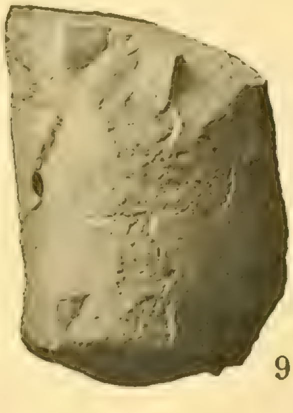

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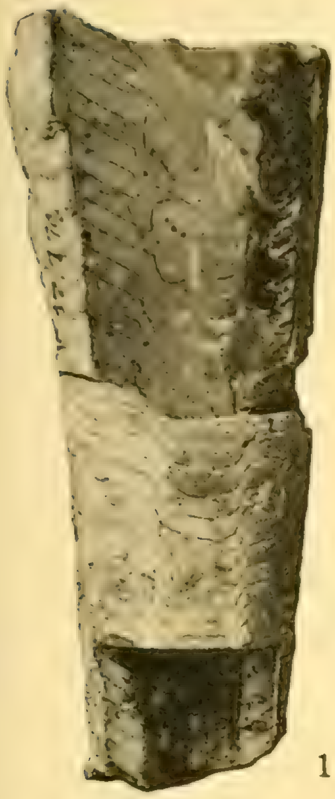
PLATE 9 (22)

Explanation of Plate 9 (22)

Figure		Page
1-7.	**Lobendoceras emanuelense** Teichert and Glenister, n. gen., n. sp.	69
	1-4. Holotype, No. 346, × 1. Ventral. 2. Dorsal. 3. Anterior. 4. Lateral. 5-7. Paratype, No. 347. 5. Lateral thin section, × 9. 6. Lateral opaque section, × 1. 7. Ventral, × 1.	
8-10.	**Aethoceras caurus** Teichert and Glenister, n. gen., n. sp.	82
	Holotype, No. 364, × 1¼. 8. Top view. 9. Oral view (the torsion of the shell is most apparent in this aspect). 10. Ventral (note the two flanges on left side).	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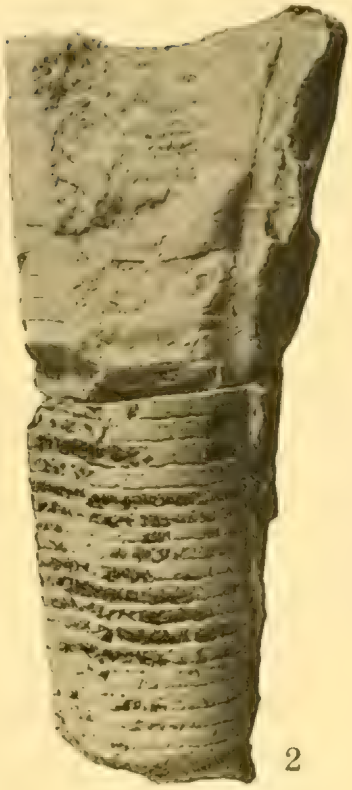
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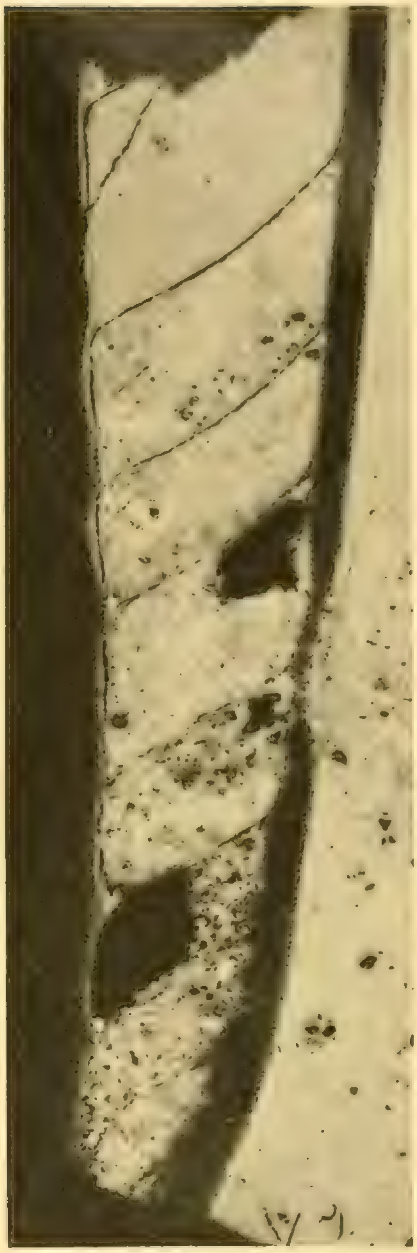
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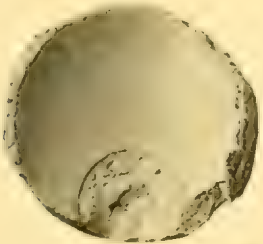
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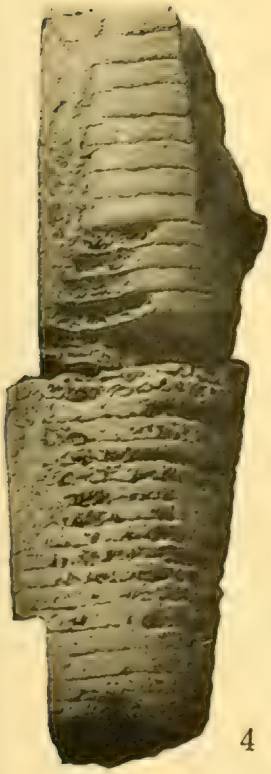
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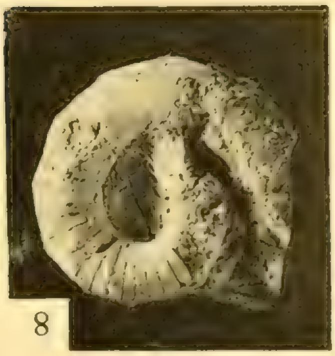
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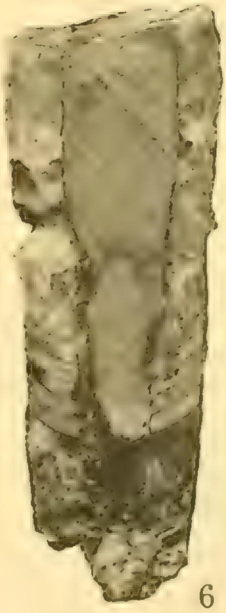
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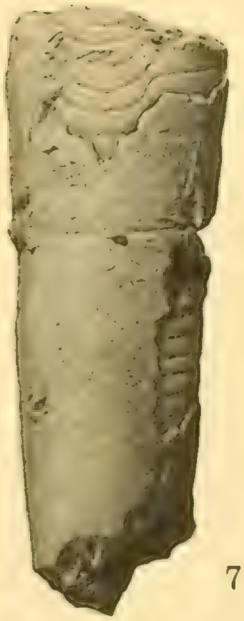
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PLATE 10 (23)

Explanation of Plate 10 (23)

Figure Page

1-7. **Aphetoceras delectans** Teichert and Glenister, n. sp. 77

1-2. Holotype, No. 359, × 1. Left. 2. Right side of anterior third of last whorl. 3,4. Paratype, No. 360, × 1. 3. Left side of anterior third of last whorl. 4. Polished surface through siphuncle. 5,6. Paratype, No. 362, × 1. 5. Ventral. 6. Lateral, × 1. 7. Paratype, No. 361, × 1.

8. **Aphetoceras desertorum,** Teichert and Glenister, n. sp. 80

Holotype, No. 363; lateral, × 1.

9. **Estonioceras** sp. 83

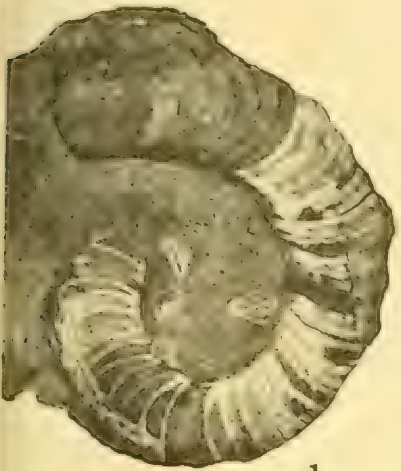
Specimen, No. 34130; lateral, × 1.

10-11. **Arkoceras** sp. 86

Specimen, No. 357, × 5; 11. Anterior. 12. Lateral.

12-15. **Pycnoceras liratum** Teichert and Glenister, n. sp. 84

Holotype, No. 358, × 1. 13. Left. 14. Natural section through centre of umbilicus. 15. Right. 16. Part of the body chamber showing the lirations.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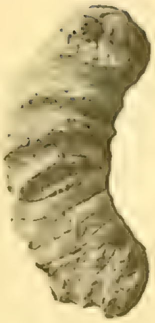
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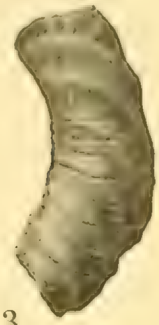
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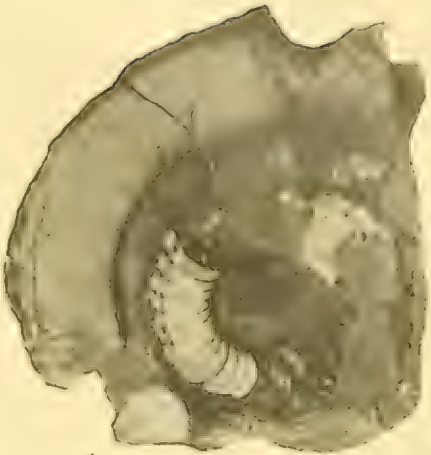
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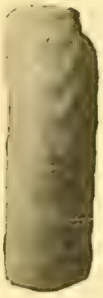
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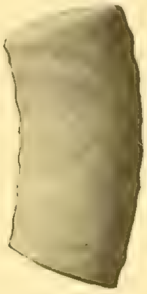
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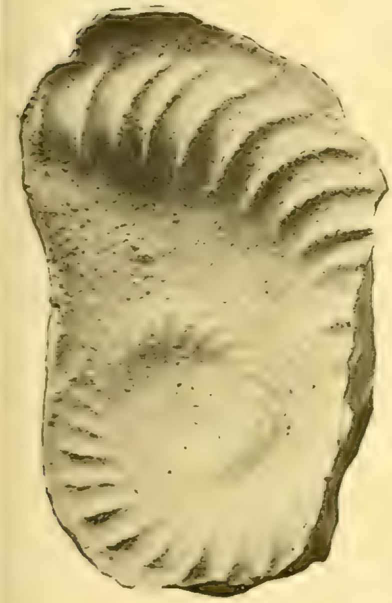
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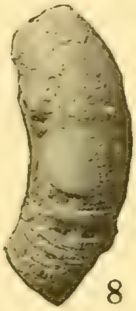
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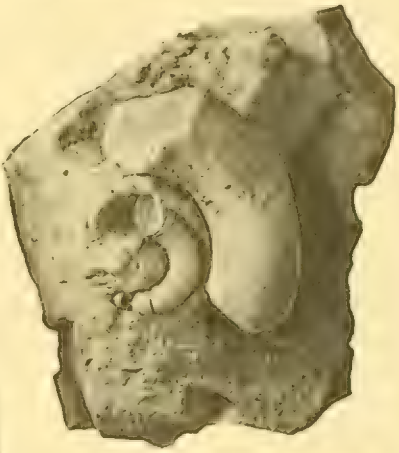
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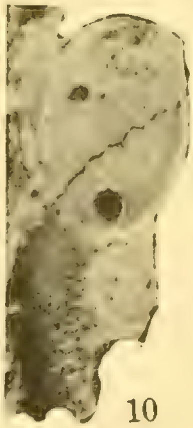
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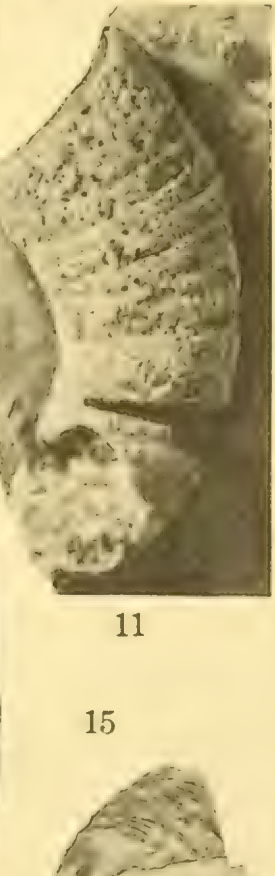
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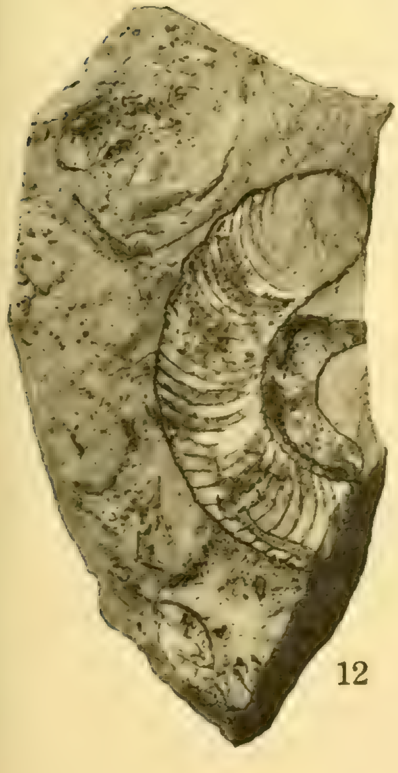
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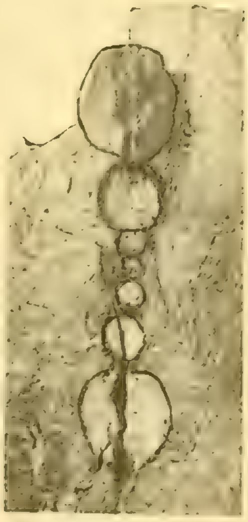
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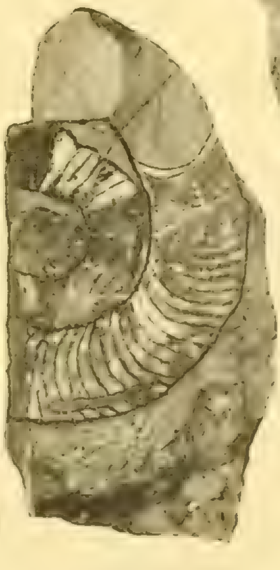
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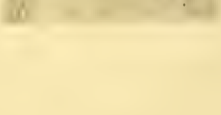
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No. 151

NEW CALIFORNIAN PLEISTOCENE EULIMIDAE

By

S. Stillman Berry
Redlands, California

July 7, 1954

Paleontological Research Institution
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NEW CALIFORNIAN PLEISTOCENE EULIMIDAE

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INTRODUCTION

Two exposures in the San Pedro area and immediately adjacent regions are particularly rich in species of the family Eulimidae. These are the Lomita formation formerly exposed at Hilltop Quarry, which for the present I tentatively refer to the extreme base of the Pleistocene, and the upper Pleistocene of Long Wharf Canyon, Santa Monica, which must lie well toward the top of the section. Both faunules seem representative of more austral conditions than prevail in our latitude at present, finding their nearest living parallels well down the coast of Lower California. Despite the possession of this common tendency their respective lists of Eulimidae are of quite different character.

At Hilltop Quarry shells of this family are infrequent and incomplete in occurrence in the coarse marl of the main deposit formerly exposed in the Quarry floor, only a single species being at all common there in good condition. Most of the fine-grained upper portion of the deposit is poor in macrofossils to ordinary examination, and it was not until I resorted to systematic screening with a fine mesh that the interesting and varied representation of Eulimidae in these upper beds began to be suspected. Subsequently the series so obtained was greatly enriched from siftings of a peculiarly rich shelly pocket in these beds excavated by Mr. Emery P. Chace. The study of all this has led to the preparation of the present paper as its initial result.

The material from Santa Monica was collected and given to me some years ago by the late Dr. F. C. Clark. It had already been partially worked up by me and is included here not only because of its intrinsic interest, but for the interesting comparisons thus made possible.

Comparison is simplified if the species thus far segregated are listed in separate columns.

Hilltop Quarry

Balcis (Balcis) aff. *micans* (Carpenter)
" (") cf. *rutila* (Carpenter)
" (") aff. *rutila* (Carpenter)
* " (") *tersa*, n.sp.

Balcis (Vitreolina) thersites (Carpenter)
* " (") *incallida,* n.sp.
" (") cf. *prefalcata* Bartsch
* " (") *obstipa,* n.s.p.
* " (") *ebriconus,* n.sp.

Long Wharf Canyon

Balcis (Balcis) micans (Carpenter)
" (") *rutila* (Carpenter)
* " (") *monicensis* (Bartsch)
" (") *compacta* (Carpenter)
* " (") *clavella,* n.sp.
" *(Vitreolina) cf. thersites* (Carpenter)
" (") sp. indet.
" (") sp. indet.
" (") *cosmia* (Bartsch)
" (") *loleta* (Jordan)
* *Eulima raymondi* Rivers

* Known only from horizon noted.

It will be noted that not more than three species can be recognized as common to the two formations, *Balcis micans, B. rutila,* and *B. thersites,* and there appears to exist a possible question respecting each of these. Four members of the list from Hilltop Quarry and one from Long Wharf Canyon have not been recognized amongst any species hitherto named, either Recent or fossil, and are accordingly described herein as new. It is further of considerable interest to note that four species from Hilltop Quarry (all but one of those for which precise determination is ventured) and three of those from Long Wharf Canyon are as yet unknown in our collections save from their type localities. One species, providing that my identification of *B. loleta* is well-advised, is known elsewhere only from the Pleistocene of San Quintin Bay. I feel, however, that it is much too early to assume that any of these are now actually extinct, as it may well be that exploration of the offshore fauna at proper depths off the coast of Lower California will reveal that most or all of them are still living at appropriate latitudes. If the same forms are still extant then the more crucial difference between the two listed faunules may turn out to be not so much one of time, considerable though it be, as of bathymetry.

Current local usage of generic names in this family for the last quarter century has been principally governed by the pronouncements of Bartsch (1917). However, Winckworth (1934: 12-13) has outlined grounds for quite a different arrangement, in the course of which he rejects *Melanella* Bowdich, 1822, because of serious question as to the generic and familial affinities of its type-species. He shows that *Strombiformis* da Costa 1778 is not susceptible to its interpretation by Iredale (1915:292-293; 1915a: 344) but must be defined in the light of the prior type designation by Harris in 1894 (Proc. Malac. Soc. Lond., 1:31), which designation entirely eliminates it from consideration as an eulimid. As Winckworth appears to ground his argument too strongly for successful assault from the bastion of evidence at present available, we can hardly refuse to follow him. This compels abandonment of *Melanella* and its replacement for the greater number of our commoner species by *Balcis* Leach, 1847, under which Winckworth suggests *Vitreolina* Monterosato as a tentative subgenus to cover the species with arcuate spires. One happy result of all this is the restoration of *Eulima* Risso, 1826, which replaces *Strombiformis* Iredale, *non* da Costa. in a conception only slightly at variance with classical usage, thus *ipse facto* restoring the old family name Eulimidae, whatever the fate of *Melanella.*

I am naming as new at the present time no species of which I have less than five specimens. Several of those still undetermined and represented by only a specimen or two may likewise eventually prove to be undescribed, or they may tie in with some named species among which there are several as yet not too well understood.

I am deeply grateful to Dr. Paul Bartsch and the United States National Museum for a number of important specimens inclusive of several paratypes, which have been of inestimable value in crucial comparisons, and to Mr. Emery P. Chace and the late Dr. F. C. Clark for the kind assistance already acknowledged.

SYSTEMATIC DESCRIPTIONS

Balcis (Balcis) clavella, new species. Pl. 1, figs. 1, 2

Description.—Shell fairly large for the group, solid, heavy, smooth, with a stout, evenly tapering, almost straight-sided spire. Whorls in excess of 10 (apical ones missing in all shells seen), almost flat to the body whorl, which is little produced and rounds out strongly to the base, its periphery subangulate in front of the lip, and this angulation likewise evident on the penultimate whorl of some specimens just posterior to the distinct and narrowly impressed suture. Base obtusely rounded, little produced. Aperture less than 25% of the altitude of the shell, oblique, pyriform, acutely angled posteriorly, slightly produced in front; outer lip fairly thick, though thinning at the margin, moderately produced at the periphery, whence it recedes smoothly into the columella; parietal wall almost flat, forming an obtusely rounded angle with the short, heavy, slightly oblique, weakly arcuate columella, the whole covered by a rather thick layer of callus, sharply bounded in front and, though well reflected in the columellar region, not completely appressed, so that the abruptness of its margin produces in some specimens almost the effect of a narrow delimiting groove. Sculpture wanting, even the growth lines and the few and uncertain varical marks being demonstrable with difficulty.

Measurements of holotype.—Alt. 8.88+, max. diam. 2.81, alt. aperture 2.22, diam., aperture 1.48 mm. The largest paratype measures, alt. 9.25+, max. diam. 2.96, alt. aperture 2.22+, diam. aperture 1.55 mm.

Holotype.—Cat. No. 10908, Berry Collection.

Paratypes.—Cat. No. 10909, Berry Collection; others to be deposited in the collections of Stanford University, the United States National Museum, and the San Diego Natural History Museum.

Type Locality.—*Upper Pleistocene* of Long Wharf Canyon, Santa Monica, California; 9 shells, collected by the late Dr. F. C. Clark.

Remarks.—The shell of this distinct species is sufficiently like no other seen by me to require any detailed comparison. In a general way it somewhat recalls that of *B. micans* (Carpenter), but it is unique in its heavy, smoothly conical shell, with almost truncate base and exceptionally short restricted aperture. I know no Recent shell like it nor have I detected its presence in any Pleistocene horizon other than that exposed at Long Wharf Canyon. The shell surface in most specimens is variously roughened, pocked, or scarred, and this doubtless contributes to the more or less complete defacement of any sculpture initially present.

The specific name proposed is a diminutive of the L, *clava,* club, and has reference to the shape and heaviness of the shell.

Balcis (Balcis) tersa, new species. Pl. 1, figs. 3, 4

Description.—Shell small, solid, smooth, polished, with an elongate-conic, moderately attenuate, almost perfectly straight-sided spire, though a very slight forward torsion may be detected apically in some specimens. Whorls about 11, the first 2½ or 3 weakly convex with the suture distinctly indented; next whorl less convex, and subsequent whorls quite flat, their suture still clean-cut and distinct, but hardly at all impressed; periphery of last whorl subangulate. Base moderately long, weakly sinuate into the pillar. Aperture pyriform, acutely angulate posteriorly, rounded in front; outer lip nearly straight to the obtuse peripheral subangulation, moderately produced in front; parietal wall weakly convex, forming an obtuse angle with the nearly straight or slightly concave, moderately oblique columellar profile about midway of the aperture, the whole covered with a thin, sharply bounded callus; columellar portion of inner lip reflected over the base and closely appressed to it until anteriorly it gradually comes away to pass imperceptibly into the free portion of the lip. Varical grooves three, with no evident inter-alignment, the last just behind and above the lip.

Measurements of holotype.—Alt. 5.03, max. diam. 1.51, alt. aperture (suture to anterior edge) 1.48, diam. aperture (edge of callus to peripheral angle) 0.81 mm.

Holotype.—Cat. No. 11199, Berry Collection.

Paratypes.—Cat. No. 11204, Berry Collection; others to be deposited in the collections of Stanford University, the United States National Museum, the San Diego Natural History Museum, the Paleontological Research Institution, and the private collection of Emery P. Chace.

Type Locality.—Lower Pleistocene, pocket or lentil in upper sandy phase of Lomita formation at Hilltop Quarry, San Pedro, California; 10 shells, mostly immature; S. S. Berry and E. P. Chace, 1936.

Remarks.—This trim and neat little species in the formal outlines of its shell somewhat suggests four of the described western species. Of these it is clearly distinct from 1) the upper Pleistocene *B. monicensis* (Bartsch) by that being a much larger species, with a wider body whorl and a relatively lower spire; from 2) the Recent *B. oldroydi* (Bartsch) by that being much less attenuate and having a less distinctly angulate body whorl; and from 3) the Recent *B. linearis* (Carpenter) of the Gulf of California, by that being scarcely half the size. The fourth species, *necropolitana* (Bartsch), is still not well known to Californian students, but the published measurements of the apparently incomplete holotype indicate a shell half again the size of my largest specimen of *tersa,* while the figure gives the impression of an appreciably narrower, more attenuate shell with a correspondingly narrowed aperture. I regret that it has been impossible to accomplish a direct comparison of these two forms prior to publication, but since *B. necropolitana* was described from the Lower San Pedro which implies a definitely cooler fauna, the differences noted seem likely to be indicative of some taxonomic distinctness.

From its several associated congeners in the Hilltop Quarry beds, the present species is readily separable by its straight and very slender form from all but *B. rutila* (Carpenter), a species with which its angulate periphery and less produced base should prevent any confusion by the discriminating student. As in the case of several other species which have been referred to *Balcis* the spire shows evidence of a slight torsion in certain aspects, so the position of the species is borderline.

The specific name chosen is derived from the L., *tersus,* correct, nice, neat,—and refers to the trim form of the shell.

Balcis (Vitreolina) obstipa, new species. Pl. 1, figs. 5, 6

Description.—Shell of fair size for the genus and subgenus, solid, smooth, polished, with an apically attenuate, doubly flexed spire, the anterior portion moderately bent to the right, the acutely rounded apex tipped a little dorsad. Whorls about 13 or 14, the first three or four weakly convex with a slightly but distinctly impressed suture; subsequent whorls nearly flat, though a trifle more convex on the side opposite to the flexure, closely applied posteriorly against the distinct but slightly impressed suture; body whorl smoothly rounded with just a hint of peripheral angulation into the weakly convex contour of the somewhat eccentrically produced base. Sculpture absent except for the fine, nearly indistinguishable growth lines and the strong varical grooves, which are completely aligned and form a continuous seamlike fold, first apparent at about the 6th or 7th whorl, thence running obliquely forward down the concave side of the spire to terminate in the suture just back of the lip, and becoming sweepingly crenate in outline by reason of the slight convexity of each varix and the small angular projection by which it ties into the next succeeding varix at the suture; final whorl without a varix, although there is a slight down-bending of the upper part of the lip just back of the aperture, which adjoins the terminus of the fold and almost imperceptibly brings the latter into alignment with the forward sweep of the lip. Aperture about 27.8% of the altitude of the shell, elongate-pyriform, acutely pointed posteriorly, obtusely rounded in front; parietal wall weakly convex, passing before reaching the median part of the aperture into the thickened, nearly straight, moderately oblique columella, the whole covered with a thin sharply bounded callus, which is notably widest in the columellar region and is there closely reflexed and appressed against the base of the whorl; outer lip rather heavy, well produced peripherally, and thence rounding back into the columellar flare.

Measurements of holotype.—Alt. 9.32, max. diam. (estimated) 3.03, alt. aperture (to suture) 2.59, diam. aperture (outer edge of reflected columellar lip to outer edge of outer lip) 1.48 mm.

Holotype.—Cat. No. 11196, Berry Collection.

Paratypes.—Cat. No. 11205, Berry Collection; others to be deposited in the collections of Stanford University, the United States National Museum, the San Diego Natural History Museum, the Paleontological Research Institution, and the private collection of Emery P. Chace.

Type Locality.—*Lower Pleistocene,* pocket or lentil in upper sandy phase of Lomita formation at Hilltop Quarry, San Pedro, California; 27 shells, partly immature or fragmentary; E. P. Chace and S. S. Berry, 1935-40.

Remarks.—This charming *Balcis* occurs in association with a somewhat more abundant allied species which I have tentatively identified as probably *B. prefalcata* (Bartsch), but its shell is decidedly more robust than that of either the latter species or *catalinensis* (Bartsch), with a larger body whorl and shorter, much more rapidly tapering spire. It is possible that *B. draconis* (Bartsch) of the Dead Man's Island Pleistocene is a near affiliate, but the description and figure indicate it to have a smaller, heavier shell with a decidedly stouter spire. I regret none the less that I am unable to institute a direct comparison of *B. obstipa,* either with this species or with the Recent *B. grippi* (Bartsch). The spire of the latter would seem to be flexed much too strongly for it to be the same thing despite Bartsch's description (1917:328) of a varical structure essentially similar to that which I have described in a little greater detail here.

The specific name proposed is taken from the L. *obstipus,* bent to one side, and refers to the shape of the spire.

Balcis (Vitreolina) incallida, new species. Pl. 1, figs. 7-10

Description.—Shell of medium size, heavy, robust, polished, with a stout, fairly acute spire which is moderately to strongly and quite unevenly flexed dorsad, or less commonly ventrad. Whorls about 10 (nearly all mature shells slightly decollate) ; extreme apex rounded, next two or three whorls convex, with suture well impressed; subsequent whorls weakly convex on the concave side of the spire and a little more so on the convex side; last whorl often attached quite obliquely to the penultimate whorl; suture distinct, moderately impressed; last whorl long, rounded smoothly and obliquely into the base. Sculpture absent except for the fine growth lines and the usually 5, distinct varices, which are more or less scattered, with only an imperfect tendency to aggregate themselves on the concave side of the spire. Aperture about 28% of the length of the shell, pyriform, acutely pointed posteriorly, smoothly rounded in front, hardly produced; parietal wall passing smoothly without angulation into the heavy, weakly concave columella, the whole covered by a thick sharply bounded callus, which recurves rather widely over the columella, its parietal edge nearly straight, thence rounds into the columellar flare at a little more than a right angle; outer lip heavy, though thinning somewhat at the edge, and slightly produced in a low wide curve peripherally.

Measurements of holotype.—Alt. 5.77+, max. diam. 2.22, alt. aperture 1.63, diam. aperture 1.26 mm.

Holotype.—Cat. No. 11197, Berry Collection.

Paratypes.—Cat. No. 11207, Berry Collection; others to be deposited in the collections of Stanford University, the United States

National Museum, the San Diego Natural History Museum, the Paleontological Research Institution, and the private collection of Emery P. Chace.

Type Locality.—Lower Pleistocene, Lomita formation of Hilltop Quarry, San Pedro, California; 26 shells taken from pit in quarry floor, S. S. Berry and R. K. Cross, 1934-37; 14 shells from pocket in fine upper marl, S. S. Berry and E. P. Chace, 1935-8.

Remarks.—This species is obviously close to the living *B. thersites* (Carpenter) of the Californian coast[1], and was at first considered as a variant of it, but as material has accumulated, including an extensive series of the immature stages, persistent differences have been noted which it seems desirable to recognize even if later studies should show them to have been over-emphasized. The Hilltop species appears not only to be consistently smaller, but its shell is narrower, the spire is more slender and often with a more irregular torsion, the aperture is smaller and shorter, and the general outline of the last two whorls is markedly less convex, whether comparison be made with living shells or with the beautiful figures of Bartsch (1917:pl. 41, figs. 2-3). Side by side I have found the two quickly and readily separable by these characters down to quite juvenile stages. Furthermore, although Bartsch described the position of the varices of *B. thersites* as "scattered", I note in nearly all my Recent material of this species a quite persistent tendency for them to form on the right (usually concave) side of the spire, a tendency which I do not observe in nearly the same degree in *B. incallida.* The body whorl oft-times is eccentrically attached, appearing not only much awry but somewhat pulled down from the whorl above so as to suggest the slipping of a tight gown. The variability in form of shell is, however, great, as is partially indicated in the figures.

The specific name is the L. *incallidus,* awkward, ungainly.

Balcis(Vitreolina) ebriconus, new species. Pl. 1, figs. 13, 14

Description.—Shell small, heavy, stout, polished, with a rapidly tapering, acutely conic, somewhat attenuate apex, which is mildly flexed the left in the two largest, to the right in two of the smaller shells.

---

[1] I have collected only a single badly decollate shell of what I take to be the genuine *B. thersites* at Hilltop Quarry (figs. 11-12).

Whorls more than eight (all shells somewhat decollate), weakly convex; suture distinct, scarcely impressed; last whorl both high and wide, rather sharply rounded and not carinate at the periphery; basal slope convex. Sculpture absent except for the fine growth lines and about three low, scattered varices rendered distinct by the sharpness of the groove bounding them in front. Aperture a little less than 30% of the length of the shell, pyriform, acutely pointed posteriorly, moderately produced and somewhat narrowly rounded in front; parietal wall slightly convex, curving obtusely into the strong, nearly vertical, weakly concave columella, the whole covered by a fairly thick, closely appressed callus, sharply bounded in front, which recurves widely over the columella and stands away from the base of the shell anteriorly where it passes into the free lip, its edge rounding back into the parietal edge at a wider than right angle; outer lip fairly heavy, thinning considerably at the margin, slightly produced mesially, and well everted basally in front of the columella.

Measurements of holotype.—Alt. 3.7+, max. diam. 1.70, alt. aperture 1.11, diam. aperture 0.96 mm.

Holotype.—Cat. No. 11198, Berry Collection.

Paratypes.—Cat. No. 11208, Berry Collection; others to be deposited in the collections of Stanford University, the United States National Museum, the San Diego Natural History Museum, the Paleontological Research Institution, and the private collection of Emery P. Chace.

Type Locality.—*Lower Pleistocene,* pocket or lentil in upper sandy phase of Lomita formation at Hilltop Quarry, San Pedro, California; 16 shells, mostly immature, S. S. Berry and E. P. Chace, 1935-40.

Remarks.—The shell of this species is most like those of *B. thersites* and *B. incallida,* but differs in the relatively slight degree of torsion, the much more symmetrical outlines, the more acute spire, and the relatively great width of the body-whorl, which approaches yet does not quite attain a peripheral angulation. The holotype is much the largest of the shells found, nevertheless the position of the last varix seems to indicate that even this example may not represent full maturity. Fortunately even the youngest stages seen are distinguishable by the characters noted.

The specific name is from the L. *ebrius,* tipsy (*meton.,* abundantly filled) + *conus,* cone. In the first meaning given it recalls the shape of the spire, yet in its metonymic sense is no less neatly applicable to the fat body whorl.

Balcis (Vitreolina) loleta, (Jordan, 1926). Pl. 1, figs. 15, 16

1926. *Melanella loleta* Jordan, California Acad. Sci., Proc., ser. 4, vol. 15, no. 7, pg. 245, 251, pl. 25, fig. 6.

Attracted by their strange beauty, the peculiar natural history of many kinds, and the interesting degree of speciation developed within what would at first sight appear very unpromising limits, I have long been interested in the Eulimidae and have been putting by frequent random notes regarding them. I had written a description of the present form as new, but a careful check with Eric Jordan's account of his *M. loleta* has convinced me that lacking direct comparison of specimens I have no sound ground for regarding this shell from the Pleistocene of Long Wharf Canyon, Santa Monica, as distinct. It has the stockiest shell of any *Balcis* I have studied. It is near to *B. ebriconus* of Hilltop Quarry in its more manifest characters; indeed the two were first thought probably identical, but the robust, nearly straight-sided spire of *B. loleta,* with hardly a trace of torsion, is quite unlike the curved, more attenuately narrowed apex of the Hilltop species. The whorls are at the same time more distinctly convex. The lack of torsion would almost throw *loleta* into *Balcis, s.s.,* but its affinities in other respects seem so definitely to lie with *B. ebriconus* and other stubbier members of the *thersites*-group that it seems misplaced away from it.

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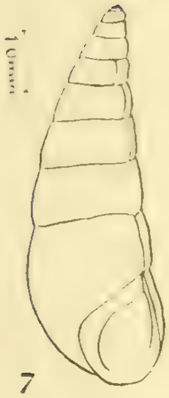

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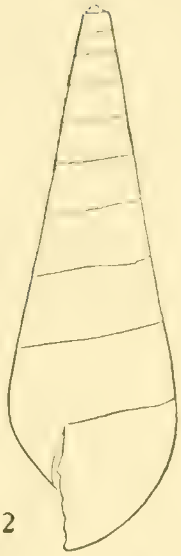

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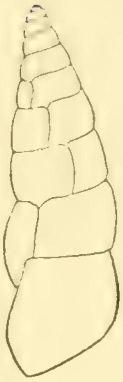

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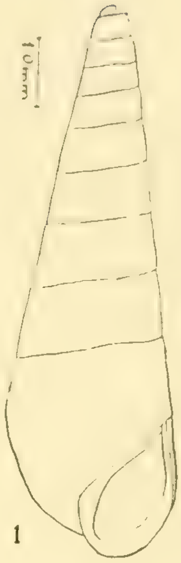

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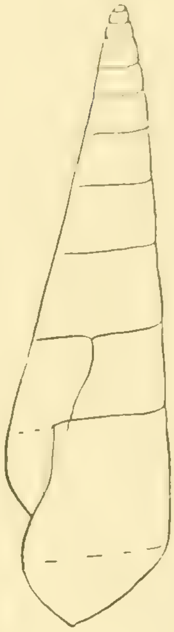

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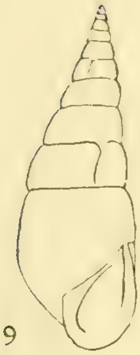

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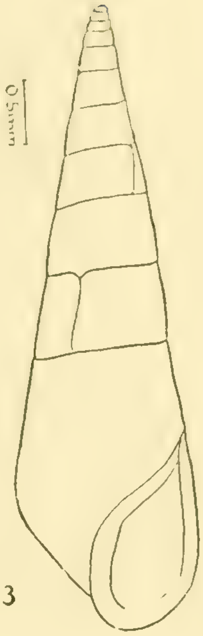

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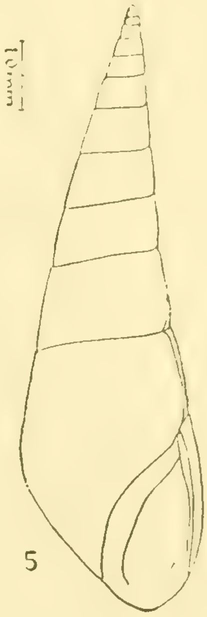

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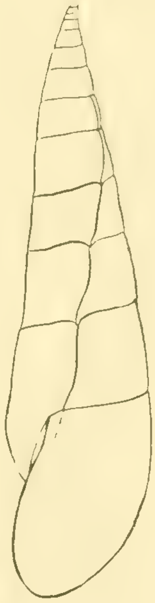

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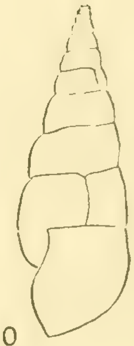

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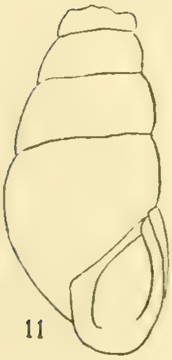

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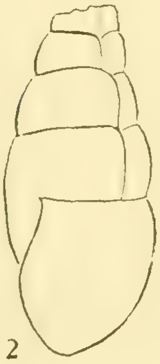

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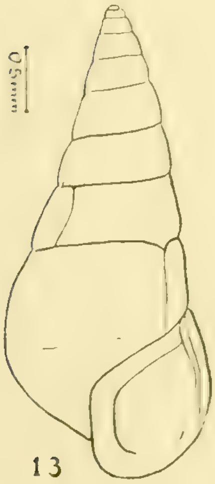

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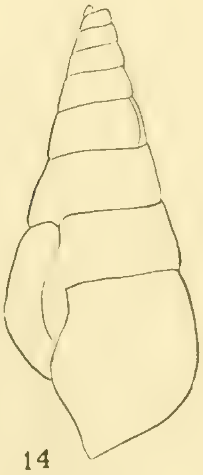

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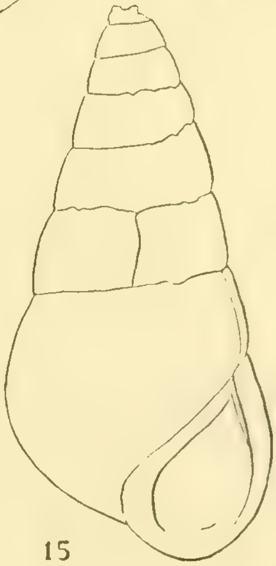

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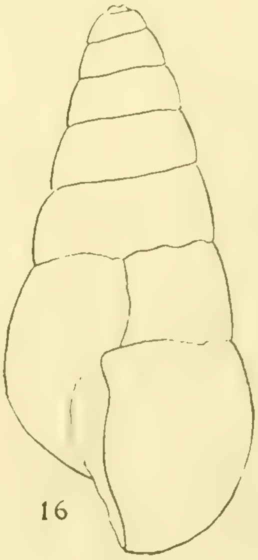

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SYSTEMS OF THE VOLUTIDAE

By

HENRY A. PILSBRY

AND

AXEL A. OLSSON

September 7, 1954

PALEONTOLOGICAL RESEARCH INSTITUTION
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Errata

Bull. 152, page 24, lines 3, 6, and 8 for *Strigilla* read *Strigatella*.

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SYSTEMS OF THE VOLUTIDAE

Henry A. Pilsbry and Axel A. Olsson

INTRODUCTION

The volutes are the aristocrats of shell collections, prized because of their beauty and the extreme rarity of many species. Most deep water species are rare, some known only from the original or type from which the species was first described; others, formerly rare, have become more generally available to collectors through the increased activities of deep sea, commercial fisheries in many parts of the world. Most shallow water species are relatively common wherever they may occur. Thus, *Voluta musica* is often found in some abundance along the beaches of northern South America from Colombia eastward. Various species of *Pachycymbiola* are common along the coast of Argentina southward to Patagonia, and specimens may often be seen in the markets of Buenos Aires. The coarse, dried, leathery foot of *Cymbium* is an article of native food along the west coast of Africa as long ago reported by Adanson. Perhaps commonest of all is the small *Aulicina nivosa* which is said to occur in great abundance at the mouths of certain rivers in Australia. Barrels of this small volute may be seen in the curio shops of Florida, the shells selling for a few cents each.

A complete classification of the Volutidae is not yet possible since it should be based not only on shell characters but on the soft parts of the animal as well. Unfortunately, the anatomy of only a few species has been fully described, hence as noted by Woodward, "it is extremely probable that we are at present incorporating within the Volutidae, several forms derived from distinct stocks, or in other words, this is not a natural family." Thus the Volutidae, as the family is at present delimited, may well contain genera not directly related, but placed together because of a certain likeness of shell form and structure.

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DISCUSSION

The classification outlined in this paper is the result of studies in connection with the proposed Treatise on Paleontology on which the junior author is engaged. It is at best but a tentative effort and various modifications of the present system can be expected with advancing knowledge of the anatomy and radula. Apparently, the first attempt at classification of the volutes, in the sense the family is understood today, was made by Lamarck in 1811. He distributed the species among four so-called small families on basis of shell form. These were named: Les Gondolieres (Cymbiolae), shell ventricose, inflated. It contained such species as *Voluta diadema, V. armata, V. aethiopica;* Les Muricines (Muricinae), shell oval, spiny or tuberculose, and included such species as *Voluta imperialis, V. pellis-serpentis, V. vespertilio, . . .*; Les Musicales (Musicales), shell oval, subtuberculose, with *Voluta hebraea, V. musica, V. chlorosina, . . .* ; and finally Les Fusoides (Fusoideae), the shell elongate, subfusiform and containing such species as *Voluta magnifica, V. ancilla, V. junonia.*

Fleming, 1822, should apparently be accepted as the author of the family name "Volutidae" although he used the spelling Volutadae, formed by adding "dae" to the generic name *Voluta.* The limits of the family were wide, as was customary in those days for generic and higher groups. He included *Voluta, Oliva, Cymbium, Marginella, Cancellaria, Mitra, Ancilla, Volvaria* and *Tornatella.* The last genus contained *Voluta tornatilis* of British writers. He placed the family between "Ovuladae" and Buccinidae.

Swainson, 1840, accepted the family name Volutidae, with the conventional spelling used for family names today. It was given wide limits and divided into five subfamilies so as to include the mitras, marginellas, olivas, and ancillarias as well as the true volutes.

From 1853 to 1857, J. E. Gray contributed three papers on gastropod classification, two of which are of major importance. The first which appeared in 1853 in the February number of the Annals and Magazine of Natural History with the title "On the Division of Ctenobranchous Gasteropodous Mollusca into larger Groups and Families," advanced a new classification including the introduction of several names for radular groups used with superfamily rank. The Rachiglossa contained the single family Volutidae, with three subdivisions: a. Volutina comprising the true volutes, b. Mitrina or the mitras, and c. Porcellanina or the marginellas. This classification was considerably enlarged, modified, and some errors were corrected in his final paper published in 1857 in "The Guide to the Systematic Distribution of Mollusca in the British Museum, Pt. 1." Thus, the mitras or Mitrana previously placed in the Volutidae were transferred to the family "Fasciolariadae," its radula, in the meantime, having become better known. Gray also contributed a special paper dealing with the Volutidae in 1855, prepared evidently as a criticism of the work of the Adams brothers in their first volume. Conservative in treatment of families and genera, but giving weight to all the characters of the shell and animal, Gray's work on the gastropods in the Guide must be regarded as a milepost in the taxonomy of mollusks.

Contemporaneous with the work of Gray was the appearance of H. and A. Adams, "Genera of Recent Mollusca." The first volume, issued in the years 1853 and 1854, treated the Volutidae, the authors placing stress on the extent of the mantle spread over the surface of the shell, a character which had been emphasized by D'Orbigny. They divided the family into three subfamilies, the Cymbiinae, Zidoninae and Volutinae. In the appendix to their second volume published in 1858, a much revised version of the classification of the Volutidae was presented, attributed to Gray. Keeping the family within the same limits as before, the volutes were distributed among three subfamilies, the radula now being given prime consideration. These subfamilies were the Volutinae, Scaphellinae and the Volutomitrinae, the earlier names of Cymbiinae and Zidoninae being dropped, their genera transferred to the Volutinae. The subfamily name of Scaphellinae is based on *Scaphella* considered by them to be equivalent to *Amoria* of Australian waters, and not as typified by *Scaphella junonia* (Shaw) of Florida.

Dall's well-known classification of the Volutidae appeared in 1890 and partly because of the eminence of its author gained immediate and general acceptance. This arrangement was based principally on characters of the embryonic shell, whether it emerged from the egg capsule with a completely formed calcareous protoconch retained in the nucleus of the adult conch, or whether it was at first apparently membranous or chitinous. If the last condition it would be lost during the intracapsular development of the embryo, becoming replaced at the apex of the conch by a calcified thick plug formed at the base of the (membranous) protoconch. The irregular or distorted shape shows that this is not the original protoconch. On this basis, Dall divided the family into two groups which he first termed the volutoid series and the scaphelloid series, later raised to a subfamily rank. The name Scaphellinae he replaced by Caricellinae, a change thought necessary because of a different interpretation of the scope of the genus *Scaphella.*

As yet but little information is available on the development of the volutid embryo within its egg capsule. A membranous or partly membranous form has actually been observed in but a single species, *Pachycymbiola magellanica* (Sowerby). Dall's arrangement based on a single shell character is not supported by structure of the radulae or other important characters. The strict application of his criterion would often lead to the separation of genera which otherwise appear closely related. Thus *Cymbium* which has a large, distorted, apical callus, which is clearly a protoconch of secondary origin, would be referred to the Scaphellinae, while *Melo* with an equally large but normally spiral, turbinate, calcareous protoconch would have to go in the Volutinae.

Partly on these grounds, Cossmann in 1899 rejected Dall's arrangement and proposed a new classification. Cossmann's effort, although it did not gain general acceptance, marked a distinct advance. It was based on all of the shell characters, those given primary consideration being the shape, position, and inclination of the columellar plaits; the presence or absence of a deep basal notch (siphonal canal); and on the degree of development of a basal fasciole (*bourrelet*). Cossmann's work is, however, marred by the practice of giving irregularly formed compound names to some of his subfamily groups — names not derived from any of the component genera and, therefore, inadmissible.

At this time, and lacking information on the anatomy of most of the volutoid genera, the best guide for relationship amongst the members of the family seem to be afforded by the radula. This is known, however, for only about 50 species. Fortunately, these are sufficiently well distributed among the principal genera to illustrate the general pattern.

The normal rachiglossate radula (as redefined by Troschel and Fischer), with 1-1-1 teeth, is retained in only a few volutoid genera and species; it is evidently a more primitive condition than the 0-1-0 radula. Thus, *Volutocorbis* amongst the Athletinae, whose geologic range extends back to the Cretaceous, has large, flat laterals in addition to a small, tricuspid central tooth. A completely triserial radular ribbon, similar in pattern to *Volutocorbis,* was figured by Schacko for *Voluta* (*Psephaea*) *concinna* Broderip. Until further checked, there is some doubt as to the correctness of Schacko's identification of his specimen or else it may be an abnormal ribbon, as later Japanese authors give only a single rachidian tooth of the usual volute pattern for the same species. Thiele mentioned small pointed lateral teeth, which were found floating loose in the caustic solution, for *Neptuneopsis gilchristi.* As pointed out by Dall, the so-called lateral teeth reported by Poirier for *Halia* are apparently the pronglike ends or sides of a yoke-shaped rachidian tooth, broken and spread apart by the pressure of the cover glass in the process of mounting. True laterals are definitely present in *Benthovoluta* and *Microvoluta,* but aside from these few examples, only the central or rachidian tooth is normally present. In most volutoid genera such as *Melo, Cymbium,* and *Aulica,* the rachidian tooth is tricuspid and the cusps are generally large and subequal. In *Voluta,* the rachidian tooth is wide, multicuspid or comb-shaped, bearing about 12 sharp, toothlike cusps, of which the outer cusps are much enlarged. Thus *Voluta,* the type genus of the family, has a radula markedly different from any other volutoid genus known. A somewhat different radular pattern is shown by the *Scaphellinae.* In these forms the base is usually deeply biramose, often assuming the shape of a wishbone, with long, narrow, spreading arms, the central cusps generally large, slender or spadelike, with or without side cusps. In *Halia* the mesocone is short.

RADULAR PATTERNS OF VOLUTIDAE

We may distinguish the following general radular patterns, arranged in form of a key:

A. Radula triserial with a tricuspid rachidian tooth and strong laterals. *Volutocorbis, Benthovoluta.*

AA. Radular ribbon normally uniserial, the laterals if present small and rudimentary.

B. Rachidian tooth large, wide, multicuspid with the extreme outer cusps much enlarged. *Voluta.*

BB. Rachidian tooth smaller, narrower, tricuspid, the cusps large and more or less subequal.

  a. The cusps long, sometimes massive and swordlike, the base thickened, arched (sharktooth base), glassy or stained with brown or orange. *Melo, Aulica, Arctomelon, Enaeta.*

  b. The cusps shorter and spaced far apart, the base usually heavy and more deeply arched. *Lyria, Calliotectum, Teramachia, Psephaea.*

  c. The cusps slender, curved, fanglike, seated on a flattened base. *Adelomelon, Miomelon.*

BBB. Rachidian tooth with a median mesocone, the side cusps sometimes weak or absent.

  aa. Base deeply forked, biramose, with narrow arms. The radular ribbon often small, the teeth weak. *Scaphella, Amoria, Aurina, Clenchina, Volutofusus, Halia, Volutomitra.*

  bb. Base a flattened plate. *Ericusa.*

VOLUTOID PROTOCONCHS

A medium to large, often gigantic nucleus or protoconch is characteristic of many Recent genera of the Volutidae although many fossil forms have only small nuclei. The scaphelloid nucleus shows a truncated, corroded or calloused, pluglike protoconch, often extremely irregular in form, and frequently tipped by a central elevated point or pimple called the calcarella by Dall, the remains of the original columella. This type is believed to be of secondary origin, formed after an earlier, membranous test developed in the egg capsule had dropped off. Other genera such as *Melo, Voluta*, and *Amoria* among Recent genera and a large number of fossil forms (*Volutopupa*) have a simple, uniformly coiled, calcareous protoconch, showing sharp, distinct sutures. Its form may be low turbinate, trochoid, to elevate pupiform, often narrowly cylindrical, its surface smooth or roughly sculptured. In these coiled forms, the initial whorl is usually small, the succeeding coils increasing steadily in size until the protoconch stage is completed. Another form, exemplified by *Alcithoe,* has a relatively large nucleus, often high or elevated but composed of a few whorls, of which the initial one is already quite large. The alcithoid nucleus is perhaps a transitional form between the horny and calcareous types. The principal difference between them is the absence of a marked calcarella. For this reason, *Alcithoe* has frequently been classed with the Scaphellinae, but a closely similar development is seen in *Voluta alfaroi* Dall (Plate 2, figure 2) and *V. virescens* Solander. A fourth type is illustrated by the Fulgorarinae in which the protoconch has a rounded, bulbous shape of a few large whorls with asymmetrical or off-axis coil. In *Mamillana* the nucleus is gigantic in size and appears much like a monstrosity. That of *Pterospira,* first described from the Eocene, is nearly as large. With the possible exception of the large *Melo* nucleus, the others have long geologic ranges, extending back at least into the Eocene. Representative volutoid protoconchs may be grouped roughly as follows.

A. Calcareous protoconchs of primary origin, composed of several closely wound whorls, the apical one very small.

1. *Volutospina.* Small, smooth surfaced, its apex pointed.
2. *Volutopupa.* A high pupiform coil of several whorls, its apex pointed.
3. *Voluta,* typical. A medium-sized, low turbinate to trochoid coil, the initial whorl small, the others uniformly enlarging. Surface smooth.
4. *Voluta,* high pupiform. An elevated, narrowly cylindrical coil.
5. *Aulicina.* Similar to typical *Voluta* but with noded whorls.
6. *Melo.* A large, low, turbinate nucleus of several whorls.
7. *Lyria.* A small nucleus of about one whorl, its apex blunt.

8. *Volutilithes.* A medium-sized nucleus, its penult whorl larger than the succeeding whorl of the conch. Apex pointed.

9. *Fulgoraria.* Small to large, bulbous nucleus, usually of a few whorls with an oblique or off-axis coil.

B. Protoconchs of an irregular form, probably secondary to an original embryonic shell with a soft or membranous test, hence deciduous, the succeeding calcareous protoconch generally showing a truncated or stumplike shape, often with a pimpled or calloused surface and sometimes a central calcarella.

10. *Cymbium.* A large nucleus of irregular form and heavily calloused.

11. *Scaphella.* A medium to large nucleus of irregular form, often subtruncate or bulbous and with a central calcarella.

12. *Caricella.* Similar to *Scaphella* but more depressed and flattened.

COLUMELLAR PLAITS

Strong folds or plaits on the columellar wall are generally considered a distinguishing character of the Volutidae although there are several genera within the family in which columellar plaits are lacking while in others they may be weakly developed only, restricted to the interior of the shell and not visible in the aperture. In most genera the anterior folds are generally the largest, a character by means of which the Volutidae may sometimes be distinguished from the Mitridae in which the posterior fold is generally the strongest. This rule is, however, not rigidly adhered to as in many volutid genera the folds are nearly equal, while in *Amoria* and *Scaphella,* the posterior fold is often the largest. The size, position, and regularity of the columellar plaits in the Volutidae is closely associated with the development of a strong basal fasciole which in turn depends upon the size of the siphonal canal notch. This relationship is well illustrated in the Cymbinae (see Plate 1, fig. 1).

In *Melo,* the arrangement is as follows:

1. The highest or posterior fold is placed opposite to the extension of the ridge, keel or line marking the upper margin of the basal fasciole. This fold varies considerably in size and in some species of *Cymbium* is so small as to be hardly noticeable.

2 and 3. Middle plaits. These are placed opposite the middle

zone of the fasciole or at points of change in the direction of the growth lines. These folds are always strong and the most persistent.

4. The lowest or anterior fold follows along the edge of the pillar of which it may be only a thickening.

In the Fulgorarinae, Scaphellinae, and Athletinae which have no well-marked basal fasciole set off by a ridge, the columellar plaits if present are generally irregular in number and in spacing. Hence, the columellar plaits of *Fulgoraria,* although numerous, are bunched together along the middle of the pillar wall giving it an appearance of distortion. In *Scaphella, Harpulina*, and *Amorena*, the posterior fold is the largest and is placed well above the short, foldlike fasciole. This condition is also repeated in *Voluta* and *Volutolyria,* where the columellar plaits are succeeded by lirations on the parietal wall.

CLASSIFICATION

Family **VOLUTIDAE** Fleming, 1822

The shells of the Volutidae show extreme range in size and form from narrowly fusiform with relatively slender spire and anterior canal to broadly strombiform with an angled or armed shoulder. In most genera, the body whorl is much larger than the other volutions and in a few forms constitutes the whole external surface. A characteristic feature of most genera is the presence of strong folds or plications on the columellar pillar; these are generally somewhat stronger anteriorly but this is not true of all species, and some genera have no columellar plaits whatsoever. In *Voluta* and *Lyria* the columellar plaits are transitional to mere lirations on the parietal wall. The siphonal canal may form a shallow or deep, notchlike cut whose growth trace may develop into a strong fasciole, often broad and cordlike which rotates upward into the aperture. Forms with a strong fasciole are usually provided with strong plaits on the columellar pillar. Lip is thin or thickened, usually smooth within. External sculpture is variable, from plain, smooth shells to others provided with strong axial ribbing and spirals, the coloration plain and dull, or highly polished and with intricate pattern. Surface in some forms may have a glazed or enamel coating, polished and smooth, and covering the sutures and the nucleus, or if unglazed, the sutures visible, the surface sometimes roughened by films of secondary deposits. Periostracum thin or thick, horn color to black. Operculum present or absent.

The living animal has a widely expanded foot and a flattened head with small, narrow, flattened, obtuse tentacles, with the sessile eyes placed at their outer base; siphonal tube with internal appendages; mantle in some forms voluminous, covering the entire shell and apex, leaving the surface beneath glazed and polished; in the majority of forms, the mantle is narrow, not extensible far beyond the aperture; Radula in the primitive forms is triserial with narrow or flattened, three-cornered marginals and a small, tricuspid central tooth; more often uniserial (0-1-0), the rachidian tooth sometimes wide, multicuspid and comb-shaped, more often tricuspid or unicuspid.

SUBFAMILIES

1. Subfamily **VOLUTINAE** Swainson, 1840 (d'Orbigny, 1841)

Shell ovate or strombiform, solid, with a high or short spire; nucleus turbinate, of several closely coiled whorls or high, cylindric; sculpture consists principally of axial riblets often forming strong nodes or sharp spines on the shoulder, sometimes wholly smooth; columellar folds usually strong, generally long and slender, and grading into lirations on the parietal wall; siphonal canal notch deep, producing a strong, basal, fasciolar fold; end of pillar appressed and recurved; outer lip becoming thickened in the adult, curving upwards towards the suture and carrying a deep posterior sinus or groove. Radula in the living species is uniserial, the rachidian tooth wide, multicuspid.

Recent genera.—Voluta Linné, 1758.

Fossil genera.—Volutolyria Crosse, 1877; *Peruluta* Olsson, 1928; *Chiraluta* Olsson, 1931. *Woodsiluta* new; *Falsilyria* new.

2. Subfamily **VOLUTILITHINAE** (new)

Shell fusiform, shouldered, solid, with an elevated spire nearly equal to the length of the aperture; protoconch relatively large, bulbous or cylindrical, composed of one or more whorls, the apical one pointed; sculpture is formed by strong, axial riblets which become spiniform or nodose on the shoulder angle, the surface otherwise smooth or marked with fine spirals; columella bearing a single, large anterior fold, the pillar wall above it plain or with weak lirations; siphonal canal notch deep, recurved at the end, and forming a strong, basal fasciolar fold. Fossil only.

Fossil genera.—Volutilithes Swainson, 1829; *Lapparia* Conrad, 1835.

3. Subfamily **ATHLETINAE** (new)

Shell at first subfusiform with a high spire and strong cancellate sculpture, sometimes becoming *Cassis*-like or strombiform in the adult, with or without a thick callous growth over the parietal wall and on the spire; protoconch small or medium-sized, of one or several whorls, and of an elevated, turbinate form with a sharp apex; body whorl with a rounded or angled shoulder, unarmed or bearing nodes or spines; sculpture more or less cancellate, at least in the young, the surface often becoming partly or wholly smooth in the adult; anterior canal straight, the siphonal canal notch shallow and usually not forming a basal fasciole; columellar plaits one or more, strong or weak; the parietal callus is a thin or heavy glaze spreading a variable distance over the ventral surface of the shell, sometimes also extending upward over the spire to form a thick, enamel coating; radula of Recent species, triserial, complete with marginals and a small tricuspid rachidian tooth.

Recent genera.—Volutocorbis Dall, 1890; *Ternivoluta* Martens, 1897.

Fossil genera.—Volutocorbis Dall, 1890; *Volutispina* R. B. Newton, 1906; *Athleta* Conrad, 1853; *Neoathleta* Bellardi, 1890; *Volutopupa* Dall, 1890. *Volutocristata* Gardner and Bowles, 1934; *Pavora* B. Clark, 1946; *Retipirula* Dall, 1907; *Tectiplica* Wade, 1916; *Parvivoluta* Wade, 1926; *Liopeplum* Dall, 1890; ?*Drilluta* Wade, 1916; ?*Paleopsephaea* Wade, 1926; *Volutovetus,* new; *Voluticella* Palmer, 1953.

4. Subfamily **LYRIINAE** (new)

Shell small or medium-sized, solid, generally subovate with a short or high spire; sutures distinct; protoconch small or of medium size, composed of 1 to 1½ whorls; sculpture generally costate but sometimes quite smooth in the adult; aperture semilunate, the outer lip straight, thickened at maturity and either smooth or dentate within; columellar plaits two or three in number, seated on a short pillar, the parietal wall above smooth or lirate; color pattern plain with spiral bands; siphonal canal notch strong, slightly recurved at end, and developing into a short, external fasciole; radular ribbon uniserial, the rachidian tooth tricuspid.

Recent genera.—Lyria Gray, 1847; *Harpella* H. and A. Adams, 1858; *Enaeta* H. and A. Adams, 1853.

Fossil genera.—Lyria Gray, 1847; *Notoplejona* Marwick, 1926; *Mitreola* Swainson, 1833; *Enaeta* H. and A. Adams, 1853; *Sannalyria* new.

5. Subfamily **FULGORARINAE** (new)

Shell fusiform with an elevated spire and a narrow or greatly inflated body whorl; protoconch small to large, bulbous, generally of a few whorls, asymmetrical or coiled with a strongly inclined axis; anterior canal generally long, straight or twisted, plain or with several collumellar plaits, usually of irregular form and spacing; siphonal canal notch shallow and not forming a marked basal fasciole; surface smooth sometimes glazed, or variously sculptured with axials and spirals; radula uniserial, the rachidian tooth tricuspid.

Recent genera.—Fulgoraria Schumacher, 1817; *Pterospira* G. Harris, 1897; *Mamillana* Crosse, 1871; *Ericusa* H. and A. Adams, 1858; *Mesericusa* Iredale, 1929; *Saotomea* Tadashige Habe, 1943; *Festilyria* new; *Iredalina* Finlay, 1926.

Fossil genera.—Lyrischapa Aldrich, 1911; *Pterospira* G. Harris, 1897; *Sycospira* Palmer, 1953; *Eucymba* Dall, 1890.

6. Subfamily **CYMBIINAE** H. and A. Adams, 1853

Shell medium or large, generally with a broadly subovate or bailer-shaped body whorl, the spire short, sometimes sunken or envolute; nucleus large, forming an elevated to truncated, calloused plug (immersed in the adult) or turbinate-pupiform, composed of several evenly coiled whorls between distinct sutures; siphonal canal notch deep and developing externally into a strong fasciole; outer lip straight, not thickened, smooth within; radular ribbon uniserial, the rachidian tooth with three strong, more or less equal cusps.

Tribe **CYMBIIDES** new

Protoconch, a calloused, truncated plug; the animal ovoviviparous.

Recent genera.—Cymbium Röding, 1798; *Cymba* Sowerby, 1826.

Tribe **MELOIDES** new

Protoconch a large, pupiform coil of several whorls and sharp sutures; animal oviparous.

Recent genera.—Melo Sowerby, 1847; *Melocorona* new; *Aulica* Gray, 1847; *Aulicina* Rovereto, 1899; *Cymbiolena* Iredale, 1929; *Cymbiola* Swainson, 1831; *Callipara* Gray, 1847; *Volutoconus* Crosse, 1871; *Cymbiolacca* Iredale, 1929; *Volutocorona* new.

7. Subfamily **ALCITHOINAE** (new)

Shell subfusiform, the spire elevated; protoconch variable in shape, scaphelloid, of secondary origin, usually of a few smooth whorls with a large initial turn or with a more or less flattened summit and central calcarella; sculpture dominantly axial forming strong or weak riblets, sometimes reduced to nodes or spines on the shoulder angle. Body whorl usually ovate, sloping, without a marked basal contraction, the anterior canal itself short, straight, the columella carrying two or more strong folds; siphonal canal notch deep developing a strong fasciole; radular ribbon uniserial, the rachidian tooth tricuspid.

Tribe **ALCITHOIDES**

Recent genera.—Alcithoe H. and A. Adams, 1853; *Cottonia* Iredale, 1934; *Pachymelon* Marwick, 1926; *Carolluta* Iredale, 1926; *Gilvostia* Iredale, 1937; *Harpulina* Dall, 1906; *Palomelon* Finlay, 1927.

Fossil genera.—Waihaoia Marwick, 1926; *Teremelon* Marwick, 1926; *Pachymelon* Marwick, 1926; *Metamelon,* 1926.

Tribe **PACHYCYMBIOLIDES** (new)

Recent genera.—Pachycymbiola Ihering, 1907; *Janeithoe*, new; *Arctomelon* Dall, 1915.

Fossil genera.—Pachycymbiola Ihering, 1907.

Tribe **ZIDONIDES** H. and A. Adams, 1853

Recent genus.—Zidona H. and A. Adams, 1853.

8. Subfamily **SCAPHELLINAE** H. and A. Adams, 1858

Shells ovate-fusiform, with an elevated spire which is generally shorter than the aperture and the body whorl ovate to globose; embryonic shell at first with a membranous test and transient (Scaphellides) followed by a secondary protoconch (scaphelloid) usually of an irregular form with a truncated, calloused summit, sometimes with a central calcarella; or fully calcified from the start, the protoconch hence having a turbinate form and composed of closely coiled whorls from a small initial beginning (Amorides); columellar wall plain or with two or more plaits; base of body whorl generally not contracted, the anterior canal itself short or lengthened and terminating in a deep or shallow siphonal notch, with or without a marked basal fasciole; surface usually smooth in the adult, with or without a covering of glaze, the earlier whorls usually axially ribbed or cancellate; radular ribbon in Recent species is uniserial, the rachidian tooth with a single, narrow mesocone, the side cusps smaller or missing and seated on a deep, yoke-shaped base with narrow arms. This subfamily may be divided into three tribes as follows:

Tribe **SCAPHELLIDES**

Embryonic shell membranous and transitory, followed by a secondary, scaphelloid protoconch, color white, yellow or pink, usually with spiral rows of brown spots. Atlantic.

Recent genera.—Scaphella Swainson 1832; *Aurinia* H. and A. Adams, 1853; *Volutifusus* Conrad, 1863; *Clenchina* Pilsbry and Olsson, 1953.

Fossil genera.—Scaphella Swainson, 1832; *Volutifusus* Conrad, 1863; *Clenchina* Pilsbry and Olsson, 1953; *Caricella* Conrad, 1835; *Atraktus* Gardner, 1937.

Tribe **AMORIDES**

Embryonic shell calcareous from the start and resulting in a well-coiled turbinate protoconch. Color plain, more often with longitudinal zigzag strips or closely variegated. Australian.

Recent genera.—Amoria Gray, 1855; *Amorena* Iredale, 1929; *Zebramoria* Iredale, 1929; *Relegamoria* Iredale, 1936; *Nannamoria* Iredale 1929; *Parvimitra* Finlay, 1930.

Fossil genera.—Amoria Gray, 1855.

Tribe **HALIDES**

Embryonic shell calcareous forming a low, turbinate protoconch; shell ovate, globose, thin-walled, its surface smooth and glossy, the columellar wall simple, deeply excavated; color white or pink with spiral rows of small brown spots; mesocone of rachidian tooth short.

Recent genus.—Halia Risso, 1826.

Fossil genus.—Halia Risso, 1826.

9. Subfamily **CALLIOTECTINAE** (new)

Shells small to quite large, fusiform to elongate-turreted, the slender spire longer than the aperture; surface smooth or marked with small, protractively bowed axial riblets, stronger on the whorls of the spire and generally slightly beaded over a grooved or channeled suture; anterior canal of medium length, its pillar wall straight, plain or with weak folds developed in the interior and not showing in the aperture; operculum corneus, unguiculate to semilunate; radular ribbon uniserial, the rachidian tooth tricuspid (Plate 3, figure 16).

Recent genera.—Calliotectum Dall, 1890; *Teramachia* Kuroda, 1931 (*Prodallia* Bartsch, 1942); *Howellia* Clench and Aguayo, 1941; *Phenacoptygma* Dall, 1918; *Neptuneopsis* Sowerby, 1898; *Fusivoluta* Martens, 1902.

Fossil genera.—Calliotectum Dall, 1890.

10. Subfamily **ADELOMELONINAE** (new)

Shell subovate with an elevated spire longer than the relatively short anterior canal; pillar with few, slender plaits, the anterior one larger; surface smooth or with rather obscure axial ribbing and spiral striation, the surface covered by a delicate periostracum; no operculum; radular ribbon uniserial, the rachidian tooth bearing three narrow, fanglike, curved cusps seated on a flattened plate.

Recent genera.—Adelomelon Dall, 1906; *Miomelon* Dall, 1907 (*Proscaphella* Ihering, 1907.)

Fossil genera.—Miomelon Dall, 1907.

11. Subfamily **VOLUTODERMINAE** (new)

Shell elongate or broadly fusiform, the spire shorter than the aperture, the body whorl large, comprising most of the shell, its base not contracted but passing with gradual slope into the long, straight anterior canal; protoconch small, turbinate; siphonal notch deep but its growth trace not producing a basal fasciole; pillar wall straight, with one or more columellar plaits; sculpture strongly cancellate or *Ficus*-like, formed by the intersection of strong ribs and spirals; in some forms the spirals persisting to form strong cords in the adult stage. Cretaceous.

Fossil genera.—Volutoderma Gabb, 1876 (*Volutomorpha* Gabb, 1876); *Ficulopsis* Stoliczka, 1867; *Rostellinda* Dall, 1907; *Rostellaca* Dall, 1907; *Rostellana* Dall, 1907; *Longoconcha* Stephenson, 1941; ?*Involuta* Cox, 1931.

12. Subfamily **VOLUTOMITRINAE** H. and A. Adams, 1858

Shell small, Mitra-like, with a small, calcareous nucleus; no operculum; radula generally triserial, the rachidian tooth similar to that of *Scaphella,* the laterals small and narrow.

Recent genera.—Volutomitra (Gray) H. and A. Adams, 1853; *Microvoluta* Angas, 1877.

Fossil genus.—Microvoluta Angas, 1877.

OF UNCERTAIN POSITION

Guivillea B. Watson, 1886; *Harpovoluta* Thiele, 1912; *Ptychoris* Gabb, 1877.

Gosavia Stoliczka, 1865, *Pholidotoma* Cossmann, 1896, and *Beisselia* Holzapfel, 1889 may be turrids.

A GENERAL KEY TO THE SUBFAMILIES OF THE VOLUTIDAE

I. Radular ribbon uniserial, formula 0-1-0
  A. Rachidian tooth wide, multicuspid, comblike (Plate 3, fig. 6). Volutinae
  AA. Rachidian tooth narrower, tricuspid, the cusps nearly equal in size. (Plate 3, figs. 4, 10, 11, 12, 13, 16).
    B. Cusps relatively wide and massive, of a knife or swordlike shape, the base of the tooth similar to that of a shark's tooth, thickened, and generally arched; glassy or deeply stained.
      C. Protoconch bulbous, of but few whorls, with a strongly off-axis coil; basal fasciole weak or absent; columellar plaits irregular in numbering and spacing. (Plate 1, fig. 3). Fulgorarinae
      CC. Protoconch or apical whorls coiled in normal fashion around central axis.
        D. Nuclear whorls small; adult shell subovate, usually small; columellar folds restricted to a short pillar or continuous with lirations on the parietal wall above; outer lip thickened and sometimes toothed. Liriinae
        DD. Nuclear whorls larger, subcylindrical to pupiform, generally of but few turns.

E. Basal fasciole strong. Columellar plaits strong. Alcithoinae

EE. No basal fasciole and no columellar folds. Calliotectinae

DDD. Nuclear whorls large and forming a calloused, truncated plug (Cymbiides), or a large, pupiform (*Cerion*-like) protoconch of several whorls (Meloides). Basal fasciole strong, bounded by a sharp keel; columellar folds strong and normally 4 in number. (Plate 1, fig. 1) Cymbiinae

BB. Cusps very narrow and slender, fanglike, seated on a flattened, platelike base. (Plate 3, fig. 9). Adelomeloninae

AAA. Rachidian tooth with a single, large mesocone, or if tricuspid the marginal cusps small. (Plate 3, figs. 5, 7, 14, 15). Scaphellinae

II. Radular ribbon triserial (1-1-1)

A. Rachidian tooth relatively wide, tricuspid, the laterals wide, flat and subquadrate. (Plate 3, fig. 17). Athletinae

AA. Rachidian tooth with a single, narrow cusp; lateral teeth small and narrow. (Plate 3, fig. 8). Shell mitroid, subfusiform; columellar plaits present. Volutomitrinae

III. Radula unknown. Fossil only.

A. Nuclear whorls small; adult sculpture strongly cancellate. Volutoderminae

AA. Nuclear whorl forming a relatively large, few-whorled protoconch with a pointed apex; sculpture generally smoothish except for minute spirals; columellar folds typically 1, anterior in position. Volutilithinae

DESCRIPTIONS OF NEW GENERA AND SUBGENERA

Subfamily **VOLUTINAE**

Genus **FALSILYRIA**, new genus

Plate 3, figure 1

Type species.—Lyria pycnopleura Gardner, 1937. For figures of this type species see: Gardner, 1937, U. S. Geol. Survey, Prof. Paper 142-F, p. 404, pl. 48, figs. 1, 2.

Lower Miocene, Chipola River, Florida.

Similar to *Voluta* Linné but with a narrower shell and higher spire; nucleus relatively small, consisting of but one rather loosely coiled whorl; sculpture formed by strong, smooth, nearly straight axial ribs, generally somewhat noded or coronated at the suture and with faint spirals showing around the base and on the canal; aperture semi-elliptical, the outer lip thickened by the last rib, smooth within; plaits on the columellar and parietal wall are similar to those of *Voluta;* of these the four or five lower ones from large, strong, sharp folds which spiral deeply into the interior while above them the plaits on the parietal wall are small and weak; end of pillar appressed and turned sharply backwards to form a recurved beak forming a deep, siphonal notch; siphonal fasciole short but strong.

Species of this group have generally been referred to *Lyria,* but its relationship lies closer to the true volutes as shown by its columellar plaits intergrading with smaller lirations on the parietal wall, and by its strongly recurved beak and short siphonal fasciole.

Genus **WOODSIVOLUTA**, new genus

Type species.—Volutospina crassiuscula Woods, 1922. For figures of this species see: T. O. Bosworth, 1922, Geology of North-West Peru, p. 104, pl. 15, figs. 6, 7; pl. 16, figs. 1a, 1b.

Lower Eocene of Peru.

Shell massive, subovate, globose, with a large, convex body whorl and a medium-length, conic spire; whorls not shouldered; spire whorls with axial sculpture, the later ones marked only by coarse lines of growth; callous glaze thin or lacking; outer lip more or less thickened and carrying a deep, posterior sinus; siphonal canal notch deep and developing a basal fasciole bordered by a keel; columella with three strong, slightly oblique folds.

Subfamily **ATHLETINAE**

Genus **VOLUTOVETUS**, new genus

Plate 2, figure 8

Type species.—Voluta petrosa Conrad, 1833. For figures of this species see: *Athleta petrosa* (Conrad), Palmer, 1937, Bull. Amer. Paleont., vol. 7, No. 32, p. 372, pl. 58, figs. 1-4, 6, 8-14.

Gulf Coast Eocene.

Shell subfusiform to substrombiform with an elevated conic spire and a medium-sized body whorl; protoconch small, composed of three or four smooth whorls forming a high, turbinate coil with a sharp apex, the passage to the first nepionic whorl shown by the assumption of bowed axials over a short area; whorls shouldered, the angle being generally spinose or nodose, the sculpture elsewhere more or less cancellate or becoming smooth, the base generally retaining strong spirals; columella with two or three plaits placed along the middle zone of the pillar; anterior canal straight, the siphonal canal notch shallow and resulting in no basal fasciole; outer lip internally denticulate in the adult or remaining smooth; a callous growth may cover the parietal wall, often spreading upward over the spire to form an enamel coating, varying in degree of thickness.

Well represented in the Eocene of the Gulf Coast by several species referred by authors to *Volutilithes, Plejona* and *Athleta.* The genus is closely related to *Volutospina* Newton of the Paris Basin Eocene, differing by its stronger columellar plaits. Its relations with *Athleta* appear less direct.

Subfamily **LYRIINAE**

Genus **LYRIA** Gray, 1847

Subgenus **SANNALYRIA**, new subgenus

Plate 3, figure 2

Type species.—Lyria pulchella Sowerby, 1849. For figures of this species see: Sowerby, 1849, Quart. Jour. Geol. Soc. London, vol. 6, p. 46, pl. 9, fig. 4; Maury, 1917, Bull. Amer. Paleont. vol. 5, No. 29, p. 73, pl. 11, figs. 10, 10a.

Miocene of Santo Domingo.

Shell ovate, globose, the body whorl large, not shouldered, the surface sculptured at first with strong axial ribbing, generally becoming smoother in the adult. The nucleus like that of *Lyria, s. s.* is small, blunt, composed of one or two smooth turns. Columellar folds like those of *Lyria* but with the parietal wall above strongly lirate throughout.

Differs from *Lyria, s. s.* by its strongly lirate inner lip and from *Harpella* H. and A. Adams by its nonshouldered whorls.

Genus **ENAETA** H. and A. Adams, 1853

Enaeta americana (Dall) Pl. 3, fig. 3

Strigilla americana Dall, 1915, U. S. Nat. Museum, Bull. 90, p. 61, pl. 9, fig. 2.

Two species of *Enaeta* are known fossil in the American Tertiary. *Enaeta americana* (Dall), described as a *Strigilla,* occurs in the Chipola Miocene at Bailey's Ferry, Fla. Another species, also described as a *Strigilla*, is *Enaeta perturbatrix* (Maury) from the Miocene of Santo Domingo.

Subfamily **FULGORARINAE**

Genus **FESTILYRIA**, new genus

Type species.—Voluta festiva Lamarck. For figures of this species see: Reeve, 1849, Conch. Icon., vol. 6, *Voluta,* pl. 12, figures 28 a-c.

Recent. Africa, the exact locality unknown.

The shell is broadly subfusiform, stout, with a spacious body whorl and an elevated subpyramidal spire; nucleus bulbous, fulgoraroïd, of one rounded whorl coiled around a tilted axis; whorls shouldered at maturity, the spire whorls sculptured with axials which become nodose on the shoulder of the last whorl; aperture subovate, with a deep commissural groove above; no fasciole; columellar plaits irregular, four, five or more in number.

Reeve's excellent figure of *Voluta festiva* resembles closely *Pachycymbiola magellanica* (Sowerby) with which it has sometimes been united, but it differs by its fulgoraroid nucleus, the absence of a fasciole, and by its more variable plaits. These characters suggest a place in the Fulgorarinae. Reeve considered *V. festiva* to be related to *Voluta hebraea,* and H. and A. Adams placed it in *Lyria* (Appendix, p. 618).

Subfamily **CYMBIINAE**

Genus **MELO** Sowerby, 1847

Subgenus **MELOCORONA**, new subgenus

Plate 1, figure 1

Type species.—Melo broderipii Gray. For figures of this species see: Reeve, 1860, Conch. Icon., vol. 13, *Cymbium,* pl. 5, fig. 3a; pl. 6, figs. 3b, c, d.

Recent, Philippines.

In shape similar to *Melo* but the spire not becoming involute, the large, pupiform nucleus remaining prominently visible at all growth stages. Shoulder of the whorls armed with strong, elevated, furrowed spines.

Genus **VOLUTOCORONA**, new genus

Plate 2, figure 10

Type species.—Voluta imperialis Lamarck. For figures of this species see: Reeve, 1849, Conch. Icon., vol. 6, *Voluta* pl. 16, fig. 36. Recent, Philippines.

Shell large, solid, the spire short, and with a large, ovate-conic body whorl; nucleus large, *Melo*-type, pupiform, generally colored dark-brown and forming a prominent apical knob; shoulder of whorls armed with large, sharp spines forming a crown; a small but definite sutural or commissural notch is present; siphonal notch deep, curved, and forming a strong, basal fasciole limited above by a sharp ridge; folds of the columella strong, four in number.

Subfamily **ALCITHOINAE**

Genus **JANEITHOE**, new genus

Plate 1, figure 8; Plate 4, figure 5

Type species.—Voluta beckii Broderip, 1847. Recent, coast of Brazil.

Shell medium to large in size, broadly subfusiform, the spire shorter than the aperture, the outer lip thin; body whorl large, subovate, plain or with short, spinose nodes on an angled shoulder; nucleus large, alcithoid, composed of about two smooth whorls with an erect, pointed calcarella at the tip; spire whorls with fine spiral sculpturing which tends to fade out on the later turns; columella with two strong plaits; the parietal callus is a light wash which extends out only a short distance beyond the aperture; siphonal canal notch deep and forms a flattened, basal fasciole not edged by a keel; radular ribbon uniserial, the rachidian tooth flattened and triserial.

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PLATES

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EXPLANATION OF PLATE 1 (25)

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1. **Melo (Melocorona) broderipii** Gray 12, 24

   Pillar showing 4 strong plaits and their position with respect to the basal fasciole. Olsson Collection.

2. **Voluta musica** Linné 13

   Showing the relations of the columellar plaits continuous with lirations on the parietal wall and the short, basal fasciole. Goajira Peninsula, Colombia. Olsson Collection.

3. **Fulgoraria rupestris** (Gmelin) 13, 20

   Anterior canal to show the absence of a basal fasciole with the columellar plaits irregularly bunched together in the middle zone of the pillar. ANSP., 185830.

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   Spire whorls showing the scaphelloid nucleus, pluglike, calloused, with obscure sutures succeeded by the sculptured nepionic whorls. Diameter of nucleus about 5 mm. Specimen from Mr. Charles R. Locklin.

6. **Amoria (Amoria) damoni** Gray 11

   Large, trochoid nucleus grading into the nepionic whorls. Australia. ANSP., 186163.

7. **Fulgoraria rupestris** (Gmelin) 12

   Spire whorls showing the bulbous nucleus with oblique coil. Diameter of nucleus about 5.7 mm. Same specimen as fig. 3.

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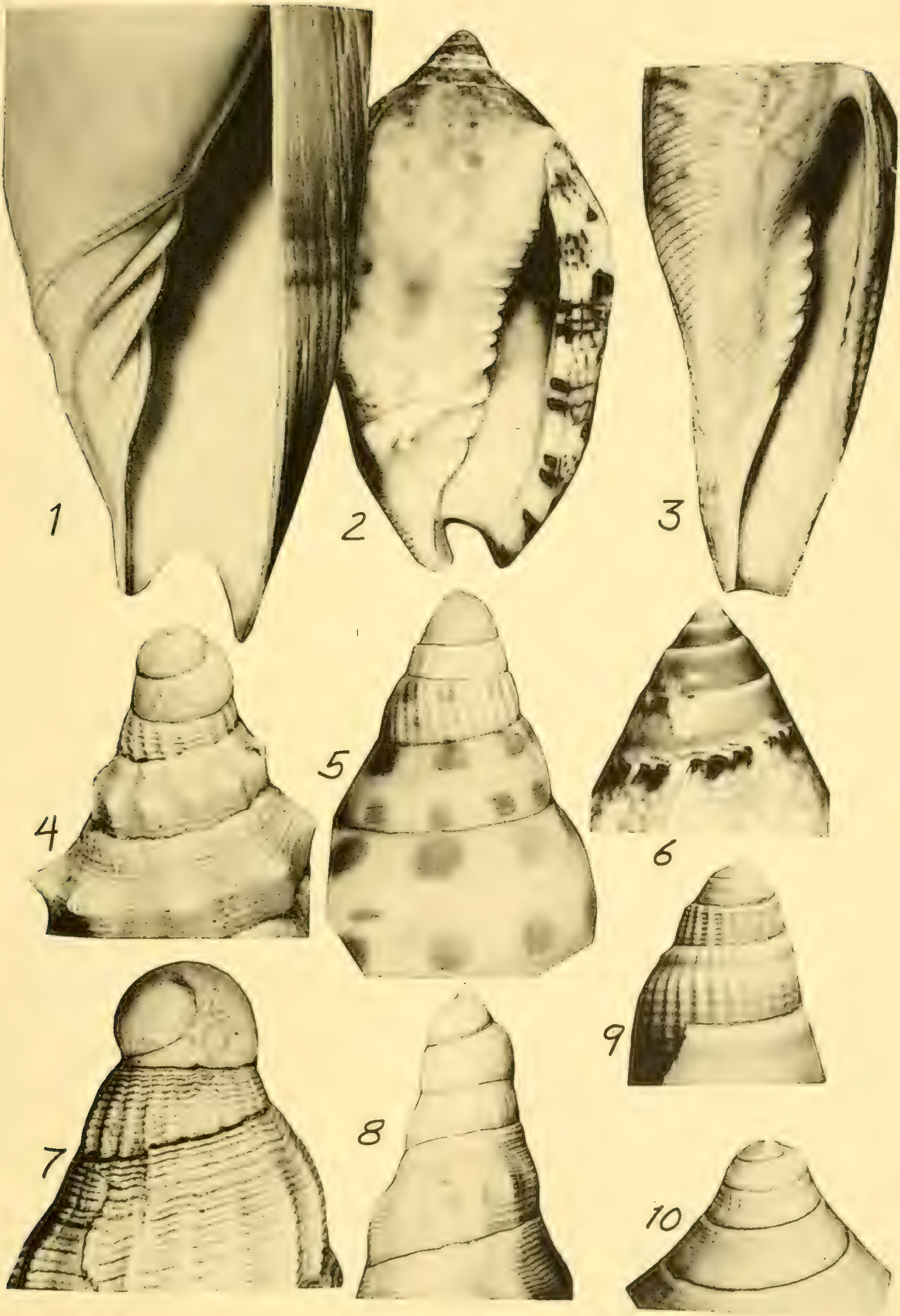
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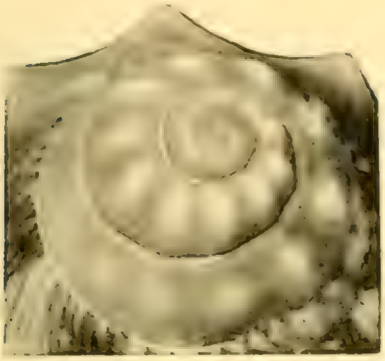
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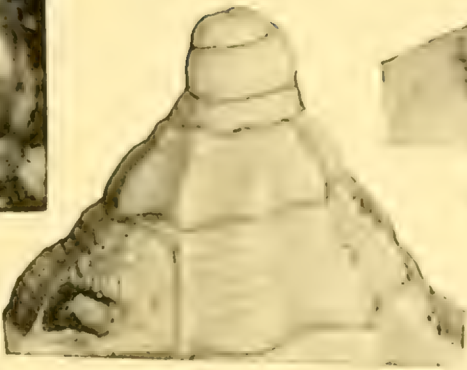
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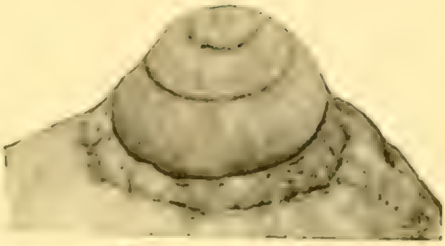
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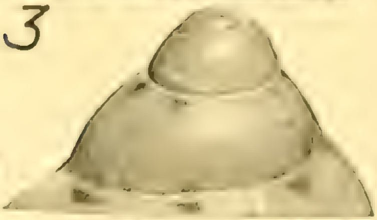
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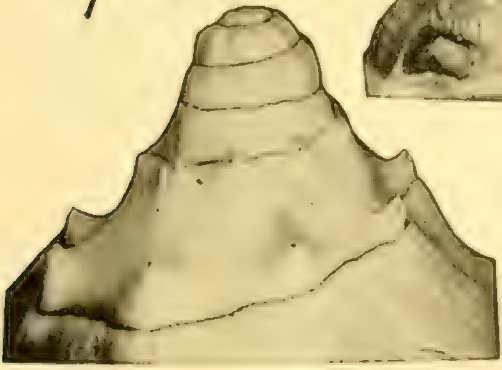
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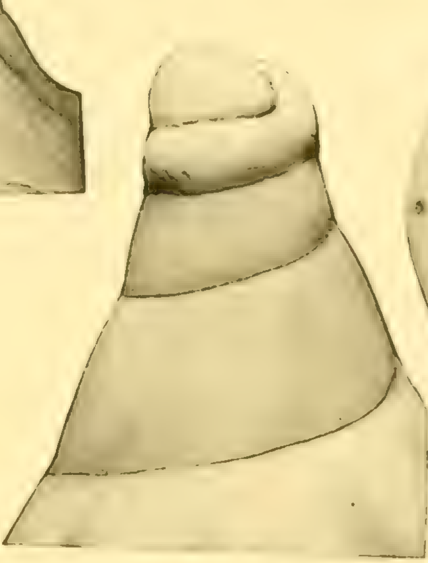
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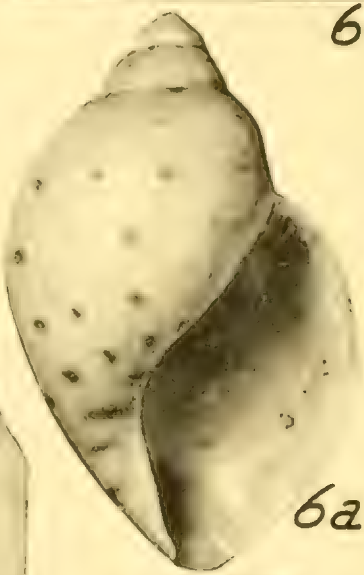
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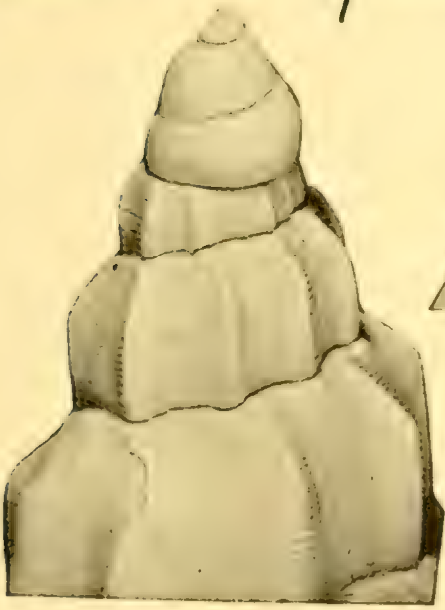
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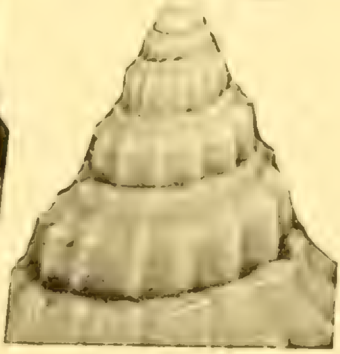
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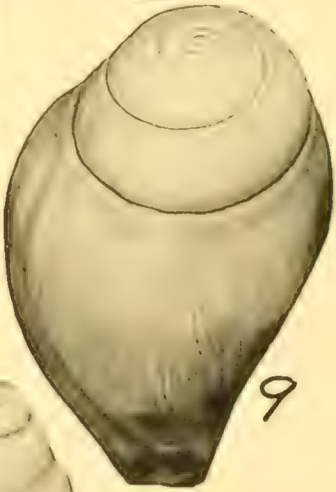
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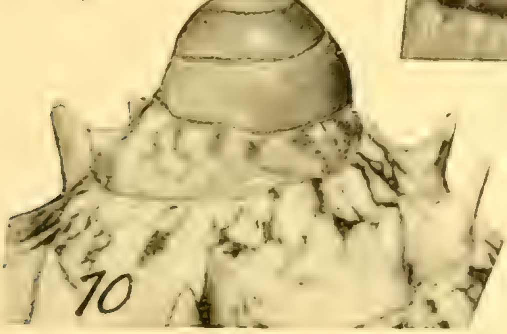
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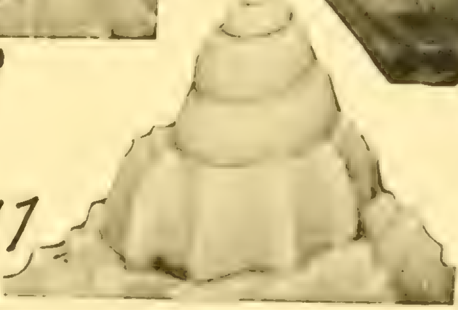
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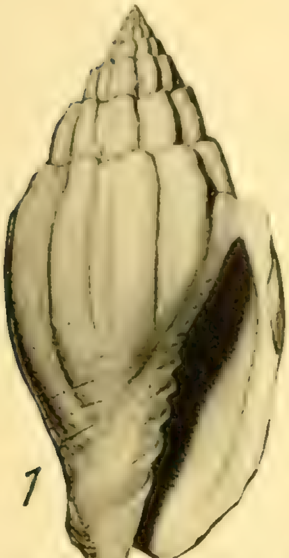
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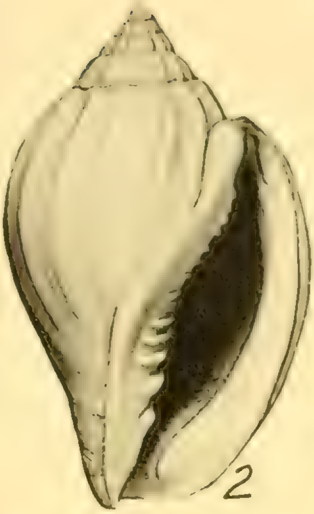
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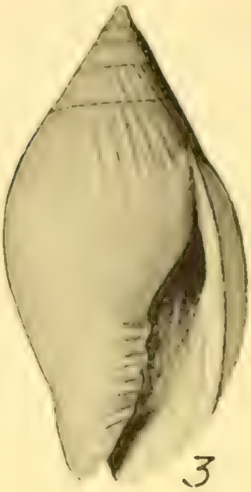
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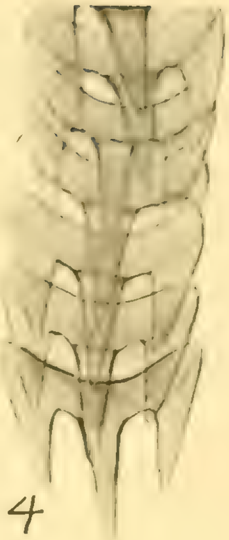
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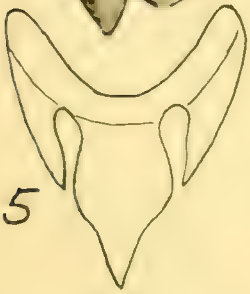
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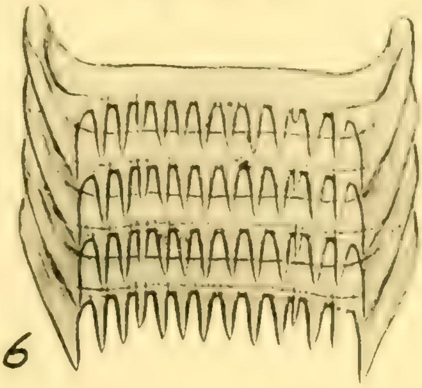
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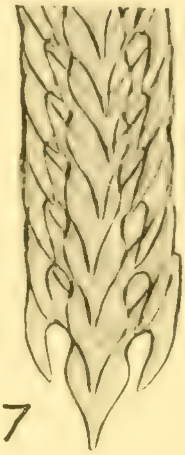
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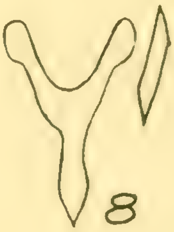
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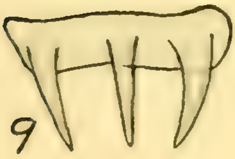
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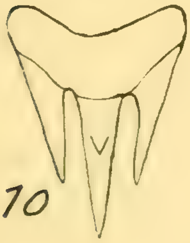
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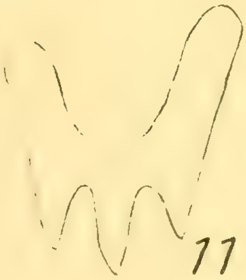
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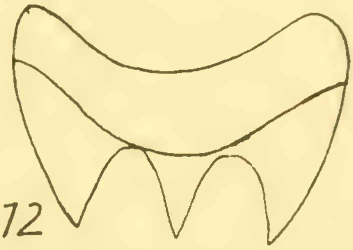
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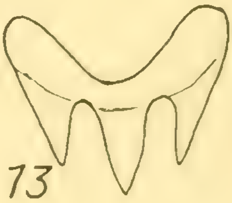
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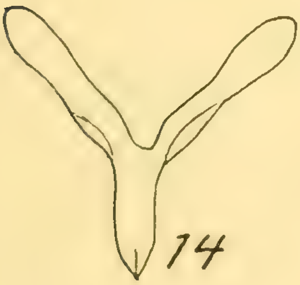
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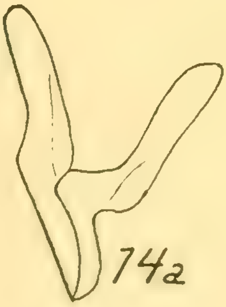
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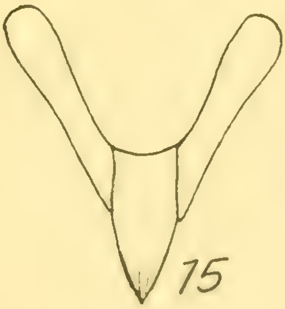
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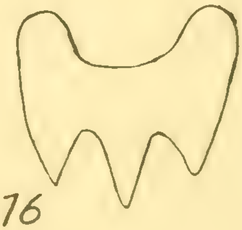
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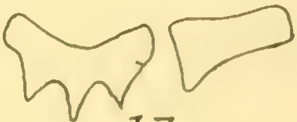
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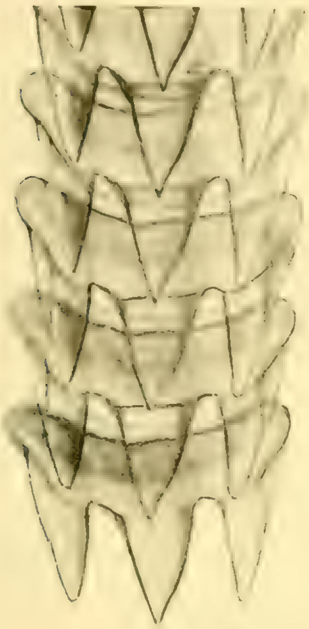
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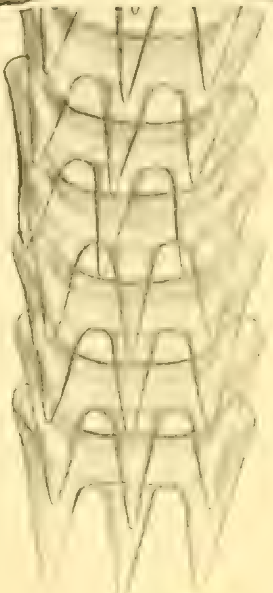
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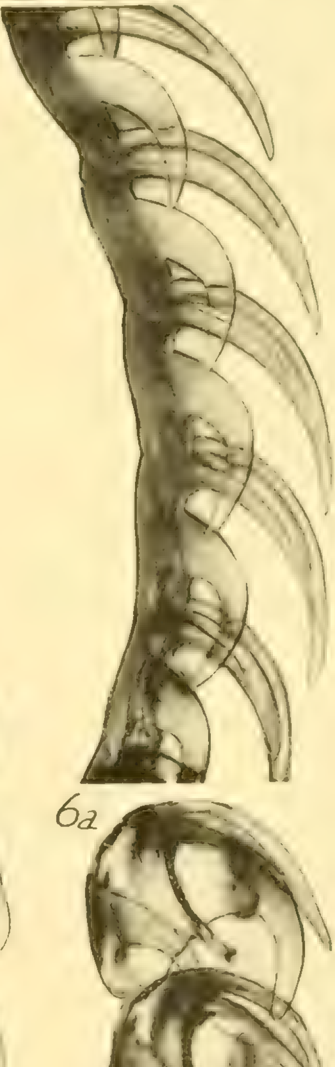
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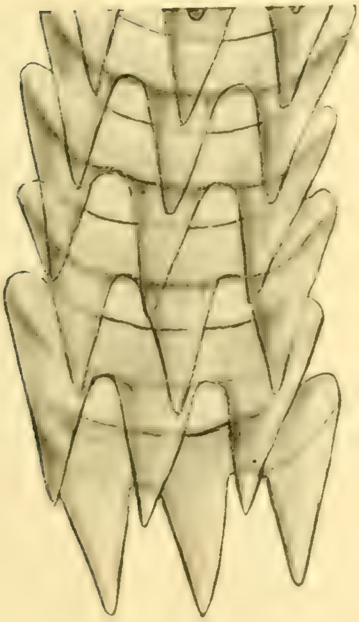
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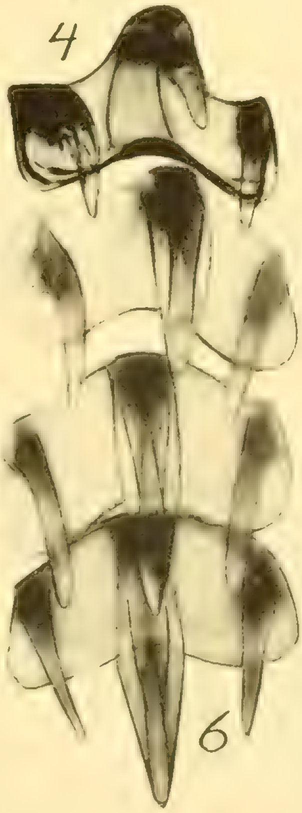
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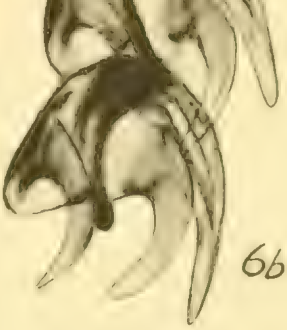
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No. 153

FIVE NEW SPECIES AND A NEW SUBGENUS IN THE PELECYPOD FAMILY CARDIIDAE

By

A. Myra Keen
Stanford University, California

December 20, 1954

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FIVE NEW SPECIES AND A NEW SUBGENUS IN THE PELECYPOD FAMILY CARDIIDAE

A. Myra Keen
Stanford University, California

ABSTRACT

New species described are: *Granocardium (Ethmocardium) pomeyroli,* Upper Cretaceous, New Caledonia; *Nemocardium (Arctopratulum) griphus,* Astoria formation, middle Miocene, southwestern Washington; *Clinocardium praeblandum,* Briones formation, upper Miocene, Contra Costa County, California; *C. pristinum,* Neroly formation, upper Miocene, Contra Costa County; and *C. hannibali,* Montesano formation, Mio-Pliocene, southwestern Washington. *Arctopratulum* is proposed as a new subgenus of *Nemocardium* (type species, *N. (A.) griphus*). Keys are included to subgenera of *Nemocardium* and to species of *Clinocardium.*

INTRODUCTION

The chance observation that the common West American heart cockle is prosogyrate started me in 1935 on what has proved to be a long-range series of cardiid studies. Justifying the proposal of a new genus, *Clinocardium,* to contain this and several similar species, led to the accumulation of a card file of some 3,000 entries and to several papers in revision and review of the family (Keen, 1936, 1937, 1950, 1951). The ambitious statement in the first of these, that "detailed discussion of the species included in the genus is withheld for a monographic study whose publication may be considerably delayed" remains unrealized, but the "two or three unnamed species," also mentioned, are herein described, and some information on species to be assigned to *Clinocardium* is offered as a partial fulfillment of the promise.

ACKNOWLEDGMENTS

I wish to thank Siemon W. Muller for advice and encouragement in the preparation of this paper, and Ellen James Trumbull and Joseph J. Graham for assistance on problems relating to the Astoria formation. I am grateful also to Frances Wagner for permission to cite some conclusions from her unpublished thesis and to Curt Dietz and Hubert G. Schenck for critical reading of the manuscript.

SYSTEMATIC DISCUSSION

Family **CARDIIDAE**

Subfamily **CARDIINAE**

Genus **GRANOCARDIUM** Gabb, 1869[1]

Type species (*subsequent designation, Stewart,* 1930).—*Cardium carolinum* d'Orbigny, 1844. Upper Cretaceous, France.

Quadrate to elliptical, ribs smooth to spinose; intercostal spaces variously ornamented exteriorly or interiorly; hinge straight or nearly so and relatively long.

Granocardium may be divided into three subgenera: *Granocardium, s. s.,* elliptical in outline, hinge slightly angulate, interspaces with two to three spinose intercalary ribs; *Criocardium* Conrad, 1870 (type species, subsequent designation, Stoliczka, 1871, *Cardium dumosum* Conrad, 1870) which is quadrate, hinge straight, not more than one spinose intercalary between ribs (sometimes none); and *Ethmocardium,* in which the intercostal spaces of the interior are pitted. All are confined to the Cretaceous.

Subgenus **ETHMOCARDIUM** White, 1880[2]

Type species (*original designation*).—*Cardium speciosum* Meek and Hayden, 1857 (*non* Adams and Reeve, 1850) =*C. whitei* Dall, 1900.

Small, quadrate, hinge straight; ribs without spines or heavy nodes; intercalary ribs not present; intercostal spaces of the interior apparently pitted or perforate.

---

[1] Paleont. California, vol. 2, p. 266.

[2] U. S. Nat. Mus., Proc., vol. 2, p. 292. Proposed as a subgenus of *Cardium.*

Ethmocardium comprises only a few known species, as follows:

Cardium (*Ethmocardium*) *ursaniense* Landes, 1940. Canada Geol. Surv., Mem. 221, p. 156, pl. 5, figs. 10-12. Pakowki formation, Alberta, Canada, Upper Cretaceous.

C. (*E.*) *welleri* Stephenson, 1941. Univ. Texas Pub. 4101, p. 195, pl. 34, figs. 13-17. Nacatoch sand, Texas, Upper Cretaceous (Maestrichtian).

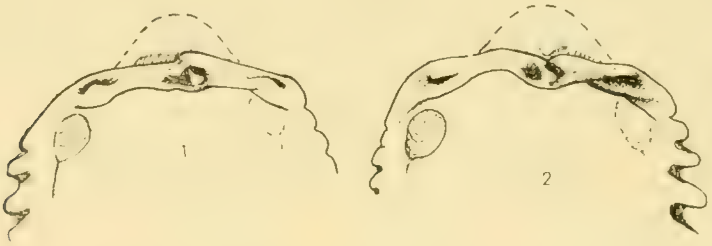
C. whitei Dall, 1900. Wagner Free Inst. Sci., Trans., vol. 3, pt. 5, p. 1074. New name for *C. speciosum* Meek and Hayden, 1857 (Acad. Nat. Sci. Philadelphia, Proc. for 1856, vol. 8, p. 274), preoccupied, from "bad lands of Judith River (Nebraska)," [*i.e.,* Montana group, Montana, Upper Cretaceous].

E. woodsi Marwick, 1944. Roy. Soc. New Zealand, Trans., vol. 74, pt. 3, p. 259, pl. 36, fig. 21. Piripauan, New Zealand, Upper Cretaceous (Upper Senonian or Maestrichtian).

A species from the Turonian of France, *Cardium alternatum* d'Orbigny, 1844 (*non* Sowerby, 1841) =*C. subalternatum* d'Orbigny, 1850, has been assigned to *Ethmocardium* by Dall, but the original figure and description show it to be a *Criocardium*, with well-developed spines between the ribs. *C. wenonah* Weller, 1907, sometimes considered an *Ethmocardium,* was a composite species based on material from New Jersey and Texas. Stephenson recognized this in 1941 and proposed a new name, *C. welleri*, for the Texas specimens. As the New Jersey specimens, at least in the original figures, do not show the internal pits of *Ethmocardium*, the restricted *C. wenonah* must be allocated to *Criocardium*, together with several other species lacking intercalary ornamentation, for which a new subgenus may eventually prove justifiable.

To the above list of four species — three from the mid-continent of North America and one from New Zealand — now is added a fifth from an intermediate location, New Caledonia.

Granocardium (Ethmocardium) pomeyroli Keen, n. sp. Pl. 1, figs. 2-4; text figs. 1,2



Figs. 1, 2. *Granocardium (Ethmocardium) pomeyroli* Keen, n. sp. Paratype, Stanford Univ. Paleo. Type Coll. No. 8290, camera lucida drawing of latex cast, slightly restored; × 1.

Shell large for the subgenus, ovate-quadrate, with about 25 ribs; ribs narrower than the interspaces, shallow, rounded on top, with vertical sides; intercostal spaces of the central 10 to 12 ribs internally bridged by thin bars of shell material which give the appearance of pits or pores when the thin outer layer is eroded away; hinge short (right valve longer than left), straight, cardinals 2a and 3b strong; anterior and posterior lateral teeth strong, the hinge plate hollowed out between laterals and cardinals; pallial line obscure, probably entire; anterior adductor muscle scars moderately large, remote from ventral margin; posterior muscle scars inconspicuous but apparently also remote; shell margins crenulate, posteriorly digitate.

Dimensions.—Holotype, height, 27 mm., length, 27, convexity (one valve), 11; 25 ribs. Paratype, height, 27 mm., length, 25.5, convexity (one valve), 10.5; 25 ribs. Paratype, height,—, length, 26 mm., convexity (one valve), 11.

Type locality.—Coal-bearing beds in area of Moméa tribe, New Caledonia. Upper Cretaceous. Collected by M. René Pomeyrol, 1951; 30 specimens.

Repositories.—Stanford Univ. Paleo. Type Coll., holotype, No. 8287, paratypes Nos. 8288-8294; other paratypes to be deposited in the collections of California Academy of Sciences, U. S. National Museum, British Museum (Natural History), Paleontological Research Institution, and the Sorbonne, Paris.

Discussion.—Compared to other members of the subgenus, this form is a giant. The New Zealand species *G.* (*E.*) *woodsi*, which has also 25 ribs, measures only 12 mm. in height and length, 4 in convexity of a single valve. The North American species have many more ribs: *G.* (*E.*) *whitei* has 40 ribs and measures 12 mm. in height, 10 in length, 4 in convexity of a single valve; *G.* (*E*). *ursaniense*, also with 40 ribs, measures 17 by 15 by 5; *G.* (*E.*) *welleri*, with 32 ribs, measures 14 by 15 by 5.5. The ribs in *G.* (*E.*) *pomeyroli* are more widely spaced, thinner, shallower in outward expression, and the interspaces are much wider than in the other species. Preservation of the material, mainly as internal molds, leaves much to be desired, making selection of a holotype difficult. The specimen chosen shows a fragment of outer surface on the center of the disk in the right valve and also shows the relationship between the apparent pits of the intercostal spaces and the thin outer layer. One paratype, No. 8290, had the hinge sufficiently preserved that latex casts could be made for both valves. In a third paratype, No. 8291, a partial external mold permitted recovery of surface sculpture by the use of latex, and it was in this that the true nature of the "pits" (actually matrix filling the spaces between thin shelly bridges across the interspaces) could be discerned. In the umbonal area where slight erosion of the outer layer had taken place, the intercostal bridging came to resemble a honeycomb. A somewhat analogous sculpture is present exteriorly in various Tertiary cardiid stocks, but in no other group is the interior of the shell reduced to a thin mesh.

Associated fossils include a few internal molds of an indeterminate gastropod, apparently one with several whorls and a siphonal canal.

The species is named in honor of the collector, M. Réné Pomeyrol, of the Société de Recherche et d'Exploitation de Pétrole en Nouvelle-Calédonie.

Subfamily **PROTOCARDIINAE**

Genus **NEMOCARDIUM** Meek, 1876[3]

Type species (*subsequent designation, Sacco,* 1899).—*Cardium semiasperum* Deshayes, 1858. Eocene, France.

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[3] U. S. Geol. Surv. Terr., Rept., vol. 9, p. 167.

Ovate-quadrate, sculpture radial, posterior slope differentiated by coarser ribbing.

As I have shown (Keen, 1950), the genus *Nemocardium* originated during early Cretaceous time and has persisted to the present, though with sharp diminution in numbers of species and with restriction of range after its heyday in the Eocene of Europe. Today *Nemocardium, s. s.,* occurs only in the Northwest Pacific and *N. (Pratulum)* only in the southern Pacific. There were several species in North America during the Eocene. In the Oligocene only four have definitely been recorded, though one so-called *Laevicardium* may qualify as a fifth. From Japan three species have been reported in the Oligocene and one in the Miocene. The new form here described is the first *Nemocardium* to be reported in the Miocene of North America. To ascertain its relationships, previous generic and subgeneric allocations of the various post-Eocene American and Japanese species have been carefully reviewed, and a somewhat revised grouping is now proposed:

Subgenus **NEMOCARDIUM**, *s. s.*

Quadrate, ribbing of posterior slope much coarser than on remainder of shell, marginal crenulations changing abruptly in size at the boundary between posterior and central slopes; ribs of posterior slope usually with spines, remainder of shell nearly smooth; hinge long and arched, hinge teeth relatively large.

The following is believed to be a complete list of post-Eocene species from the North American-northeast Asian area:

N. (*N.*) *bechei* (Reeve), 1847. Recent, off Japan.
diversum (Conrad), 1847. Middle Oligocene, Mississippi.
toriii (Nomura), 1933 [*sic*]. Mio-Pliocene, Japan.
waynense Mansfield, 1940. Middle Oligocene, Mississippi.
weaveri (Anderson and Martin), 1914. Lower Oligocene, Oregon.

Subgenus **PRATULUM** Iredale, 1924[4]

Type species (*original designation*).—*Cardium thetidis* Hedley, 1902. Recent, Australia.

Quadrate, usually smaller than *Nemocardium, s. s.,* with posterior slope set off by one or two narrower ribs but with only slight change in size or in width of marginal crenulations; fine wavy secondary concentric sculpture present on entire disk.

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[4] Linn. Soc. New South Wales, Proc., vol. 49, p. 182.

No species of this subgenus have been detected in the North American or western Pacific Tertiary. There are two in Europe that seem to belong here and several in the New Zealand-Australian area.

Subgenus **KEENAEA** Habe, 1951[5]

Type species (original designation).—Cardium samarangae Makiyama, 1934. Recent, Japan.

Smaller than *Nemocardium, s. s.*, with secondary concentric lamellae on posterior ribs; the latter not sharply differentiated. Differs from *N.* (*Pratulum*) by the presence of the concentric lamellae on ribs and a tendency toward fine beading on ribs of the central part of the disk. Included species are:

N. (*K.*) *alaskense* (Clark), 1932. Upper Oligocene, Alaska. [Tentative assignment, as the holotype, the only known specimen, is decorticated and does not show posterior ribbing well.]

centifilosum (Carpenter), 1866. Recent, California to Washington (also in the Pleistocene).

iwakiense (Makiyama), 1934. Upper Oligocene, Japan.

lorenzanum (Arnold), 1908. Upper Oligocene, Washington and California.

samarangae Makiyama, 1934. Recent, Japan.

Subgenus **ARCTOPRATULUM** Keen, new subgenus

Type species.—Nemocardium (*Arctopratulum*) *griphus* Keen, n. sp.

Ovate-trigonal, hinge short, with relatively weak teeth; ribs of posterior slope not markedly wider than on remainder of shell, smooth, with occasional secondary concentric laminae; ribs of remainder of shell often slightly beaded or with concentric threaded sculpture.

Relationships to other subgenera may be shown best in a key:

1. Posterior ribs markedly wider and heavier than those of remainder of shell, usually with spines on the crest .... *Nemocardium*
Posterior ribs not markedly wider 2

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[5] Genera of Japanese Shells: Pelecypoda, No. 2, p. 152.

2. Outline ovate-quadrate, hinge relatively long and arched 3
Outline ovate-trigonal, hinge relatively short .... *Arctopratulum*

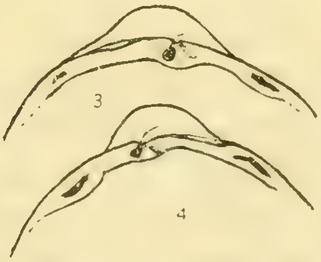
3. Secondary lamellae on posterior slope only .... *Keenaea*
Secondary sculpture not confined to posterior area .... *Pratulum*

The name *Arctopratulum* (gender, neuter) is coined from *Pratulum* by addition of the Latin *arctus,* narrow, referring to the contracted dorsal margin of the shell.

Species to be included in this new subgenus are:

N. (*A.*) *ezoense* Takeda, 1953[6]. Upper Oligocene, Hokkaido, Japan.
griphus Keen, n. sp. Miocene, Washington.
tristiculum (Yokoyama), 1924[7]. Upper Oligocene, Japan.
yokoyamai Takeda, 1953[8]. Upper Oligocene, Sakhalin Island.

Nemocardium (Arctopratulum) griphus Keen, n. sp. Pl. 1, figs. 12, 14, 17; text figs. 3, 4



Figs. 3, 4. *Nemocardium (Arctopratulum) griphus* Keen, n. sp. 3. Paratype, Stanford Univ. Paleo. Type Coll., No. 8297; 4. Paratype, No. 8296. Camera lucida drawings of hinge; × 1.

Rounded-trigonal, with about 70 moderately fine evenly spaced ribs of which 18 are on the posterior slope and 52 on the central and anterior slopes of the disk. Ribs of posterior slope narrower, with wider interspaces than those of the remainder of the disk, slightly beaded; secondary concentric lamellae occasionally present but not so readily preserved as in other species of the subgenus. Ribs of central slope low, with lightly incised interspaces, crossed by threadlike concentric sculpture, suggesting a woven texture where well developed. Hinge relatively short, arched, hinge plate narrow and teeth weak. Fragmentary hinges of available left valves show that 2a is stronger than 2b; in the right valve, 3a is weak, 3b strong; small anterior and posterior lateral teeth present in both valves. Pallial line long, entire; adductor muscle scars remote from the ventral margin, at ends of the short hinge plate.

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[6] Takeda, 1953, p. 82, pl. 9, figs. 1-9; pl. 10, figs. 1-2; pl. 11, fig. 1. (Holotype and one paratype here refigured; an additional paratype lot in Stanford Univ. Paleo. Type Coll., No. 8304.)

[7] Jour. Coll. Sci. Imp. Univ. Tokyo, vol. 45, art. 3, p. 16, pl. 3, figs. 5-7.

[8] Takeda, 1953, p. 84, pl. 9, figs. 10-12; pl. 11, fig. 4.

Dimensions.—Holotype, height, 31 mm., length, 32, convexity (both valves), 22; paratype (right valve), height, 34 mm., length, 36, convexity, 12; paratype (left valve), height, 33 mm., length, 33, convexity, 11.5.

Repositories.—Holotype, Stanford Univ. Paleo. Type Coll., No. 8295; paratypes, Nos. 8296, 8297. Other paratypes in collections of California Acad. Sci., Univ. California, U. S. National Museum, and Paleontological Research Institution.

Type locality.—Stanford Univ. loc. NP-243, on middle fork of Wishkah River, 14 mi. N. of Aberdeen, Grays Harbor Co., Washington, on line between sections 1-2, T. 19 N., R. 9W., collected by Harold Hannibal, 1912. Astoria formation, middle Miocene.

Other localities.—Stanford Univ. loc. NP-244, west fork Wishkah River, sec. 35, T. 20 N., R. 9W.; NP-248, Wishkah River, 10 mi. N. of Aberdeen; NP-249, Wynoochee River, sec. 8, T. 18 N., R. 8 W.; NP-78, seacliffs about 1 mi. S. of Taholah, Grays Harbor Co., all collected by Harold Hannibal. Middle fork of Wishkah River near Aberdeen, Wash., collected by R. W. Berger. California Acad. Sci. loc. 201, Wishkah River 2 mi. N. of Wishkah P. O.

Stratigraphic horizon.—The type locality, NP-243, and NP-244 are mapped by Weaver (Univ. Washington Publ. in Geol., vol. 4, pl. 7A, 1937) as Astoria. Localities NP-248 and 249 and California Acad. Sci. loc. 201 fall in areas mapped as Montesano. However, the matrix in which all the specimens occur is a clay shale such as Weaver described for the upper Astoria, not a sandstone such as that of the superjacent Montesano. Hence, although published geologic maps would suggest a range in age, the uniform matrix, the associated fossils (including Foraminifera), and the field notes made by Harold Hannibal point to a limited range in the upper part of the Astoria formation, and thus to a middle Miocene age.

Discussion.—One would assume that this *Nemocardium* should be intermediate between one of the Oligocene forms—*N. weaveri* or *N. lorenzanum*—and the Recent *N. centifilosum*, but so simple and obvious a line of descent seems not to have taken place. *N. weaveri,* except for lacking spines on the posterior ribs, is a typical *Nemocardium. N. lorenzanum* and *N. centifilosum* may be grouped together by their small size and secondary sculpture on the posterior slope, but *N. griphus,* with its contracted dorsal margin, does not closely resemble them; rather, its nearest relatives seem to be three Japanese Oligocene species, two of which have only recently been described (Takeda, 1953). The type figures of one of these, *N. ezoense*, are here reprinted for comparison (Pl. 1, figs. 10, 13).

The name *griphus* is a Latin noun—gender masculine—the primary meaning of which is "fish-basket", descriptive of the textured surface of the ribs; a secondary meaning of "puzzling problem or riddle" is not inappropriate.

Subfamily **LAEVICARDIINAE**

Genus **CLINOCARDIUM Keen, 1936**[9]

Type species (*original designation*).—*Cardium nuttalli* Conrad, 1837. Ribs prominent except on posterior slope; beaks markedly prosogyrate; hinge long and arched, ligament long, low, narrow.

The species of this genus have often been assigned to *Cerastoderma,* a group that I regard as restricted to the eastern Atlantic. *Clinocardium* differs in the inclined beaks, the more numerous ribs, the long low ligament, and the arched hinge line. There are more points in common with *Laevicardium*, but the latter has much less prominent ribs and a shorter, higher ligament. No other cardiid genus has the strongly prosogyrate beaks. The metropolis is in the north Pacific, ranging in time from Miocene to Recent, in Japan, Kamchatka, Alaska, and northwestern United States. One Recent species is distributed through the Arctic province to the north Atlantic.

The morphologic relationships of the three new species here described to the others previously assigned to *Clinocardium* will be shown in the form of a key following the descriptions.

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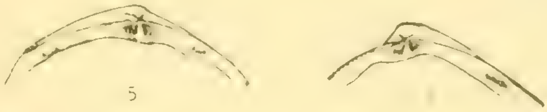
[9] San Diego Soc. Nat. Hist., Trans., vol. 8, No. 17, p. 119.

Clinocardium praeblandum Keen, n. sp. Pl. 1, figs. 1, 6; text figs. 5,6

"*Cardium quadrigenarium* Conrad," Clark, 1915, Univ. California Publ., Bull. Dept. Geol., vol. 8, pl. 47, fig. 3. Univ. California loc. 307. (Not *C. quadragenarium* Conrad).



Figs. 5,6. *Clinocardium praeblandum* Keen, n. sp. 5. Hypotype, Stanford Univ. Paleo. Type Coll. No. 8299; 6. Hypotype, No. 8300. Camera lucida drawings of hinge; from S.U. loc. C-162, Briones formation; × 1.

Trigonal, subequilateral, ventricose; dorsal margins joining ventral in a broad curve; ventral margin arcuate; umbones low, beaks slightly inturned; sculpture of 35 to 40 smooth radial ribs (40 on holotype), faintly defined on posterior slope; ribs in cross section arched, interspaces linear.

Dimensions.—Holotype, height, 37 mm., length, 36, convexity (one valve) 16 mm.; paratype (No. 32916), height, 34 mm., length, 39, convexity (one valve), 13 mm.; paratype (No. 14835), height, 33 mm., length, 33, convexity (one valve), 14 mm.; paratype (No. 32918), height, 34 mm., length, 35, convexity (one valve), 14 mm.; number of ribs 35.

Repositories.—Univ. Calif. Mus. Paleont., holotype, No. 14836; paratypes, Nos. 32916, 14835, 32918. Hypotypes, Stanford Univ. Paleo. Type Coll., Nos. 8299-8300; cast of holotype, No. 8298.

Type locality.—West end of Las Trampas Ridge near Walnut Creek, Concord Quad., Contra Costa Co., California, collected by Bruce L. Clark.

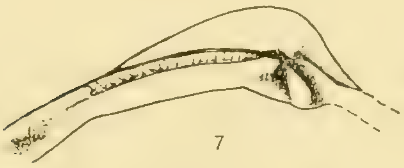
Other localities.—Univ. California locs. 307 and 1947, near Shell Ridge, Contra Costa Co. Stanford Univ. locs. C-158, Cresta Blanca, Arroyo del Valle, near Livermore; C-160, Verona road cut; C-162 (no exact loc.); C-168, Hayward Pass, all in Pleasanton Quad., Alameda Co.; S.U. loc. C-176, Alum Rock Canyon, San Jose Quad., Santa Clara Co.; all in California.

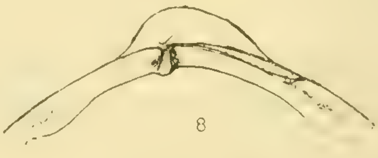
Stratigraphic position.—Briones formation, lower upper Miocene, in a moderately well cemented buff sandstone.

Remarks.—Because of the numerous ribs, this species and *C. pristinum* Keen, n. sp. have been confused by authors with the Recent *Trachycardium* (*Dallocardia*) *quadragenarium*, a form that has well-developed spinose ribs on the posterior slope and a relatively short, straight hinge. In outline, number of ribs, and degree of ventricosity this new species agrees well with the Recent *C. blandum* (Gould) but differs in being considerably larger, an average *C. blandum* having a height of about 25 mm. It is one of the earliest, if not the earliest, species of *Clinocardium*. Another Briones form, tentatively assigned by Trask (Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 13, p. 150, pl. 5, fig. 3, 1922) to "*Cardium corbis* (Martyn), n. var.", is probably *Trachycardium schencki* (Wiedey), 1928, as recognized by Wiedey in 1929 in an unpublished Stanford University thesis but overlooked by Keen and Bentson in the "Check List of California Tertiary Marine Mollusca" (Geol. Soc. Amer., Spec. Paper 56, p. 33, 1944).

Clinocardium pristinum Keen, n. sp. **Pl. 1, figs. 9, 15; text figs. 7, 8**

?*Cardium (Cerastoderma)* cf. *corbis* (Martyn), Etherington, 1931, Univ. California Publ. Bull. Dept. Geol. Sci., vol. 20, p. 77, 5, fig. 11. Astoria formation, southwestern Washington, Miocene.





Figs. 7,8. *Clinocardium pristinum* Keen, n. sp. 7. Holotype Univ. Calif. Mus. Paleo. No. 14838. 8. Paratype, U.C. No. 14837. Camera lucida drawings of hinges, slightly restored; × 1. San Pablo group, Miocene, Contra Costa Co., Calif.

Trigonal, inequilateral, ventricose; posterior dorsal margin straight, sloping downward at an angle of about 30°, meeting the truncate posterior margin at an angle of 140°; ventral and anterior margins broadly rounded; beaks at the anterior third, moderately inturned below the prominent, strongly curved umbones; ligamental area long, escutcheon faintly outlined; lunule absent; sculpture of 42-48 radial ribs (46 on holotype); ribs on the posterior slope tending to be obsolete; in cross section ribs flattened at the top, sloping at an angle of about 45° to the narrow interspaces; hinge as in *C. nuttalli* (Conrad), with 2a and 3b strong, 2b and 3a weak.

Dimensions.—Holotype, height, 50 mm., length, 53, convexity (one valve), 18; paratype, height, 40 mm., length, 44, convexity (one valve) 16, number of ribs 46. Four additional measured specimens (U. C., No. 32917) show the following for height, length, and convexity of one valve in mm., resp.: a. 30 x 29 x 10; b. 27 x 30 x 12; c. 25 x 30 x 12; d. 20 x 23 x 8.

Repositories.—Holotype, Univ. California Mus. Paleo., No. 14838; paratype, No. 14837; hypotypes, No. 32917, collected by Bruce L. Clark. Cast of holotype, Stanford Univ. Paleo. Type Coll., No. 8301.

Type locality.—Southwest part of Shell Ridge, near Walnut Creek, Concord Quad., Contra Costa Co., California. San Pablo group, probably Neroly formation, upper Miocene.

Other localities.—California Acad. Sci. loc. 1811, Tassajero Creek, Mount Diablo Quad.; Stanford Univ. loc. C-53, Kings Ranch, head of Walnut Creek; Stanford Univ. loc. C-54, Lone Tree Point, San Pablo Bay; S. U. loc. 2242, Railroad tunnel west of Tormey; all in Contra Costa Co., California.

Stratigraphic position.—Cierbo-Neroly formations, San Pablo group, middle upper to upper upper Miocene, in a coarse-grained buff to bluish sandstone often poorly cemented and chemically weathered.

Remarks.—This species resembles *C. nuttalli* and *C. meekianum* in its obliquity and high umbones, but it has 10 to 15 more ribs and is relatively longer for its height. The specimen figured by Etherington from the Astoria of Washington is doubtfully referred here. Slodkewich (1938, fasc. 19, p. 154) assimilated it to his *Laevicardium* (*Cerastoderma*) *etheringtoni,* but this species (which may be a *Fulvia* rather than a *Clinocardium*) is more nearly equilateral, with higher and narrower umbones. If the Astoria form is *C. pristinum*, it would extend the stratigraphic range, for the Astoria is at least in part middle Miocene. However, there is also a possibility that better preserved material will prove it to be an unnamed species or the ancestral stock of *C. coosense.*

The name *pristinum* is from a Latin adjective meaning early or ancient.

Clinocardium hannibali Keen, n. sp. **Pl. 1, fig. 16; text fig. 9**

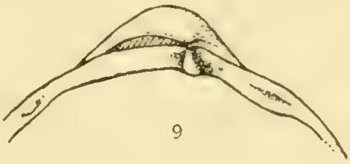


Fig. 9. *Clinocardium hannibali* Keen, n. sp. Paratype, Stanford Univ. Paleo. Type Coll. No. 8303. Camera lucida drawing of hinge; ×2. Montesano formation, Mio-Pliocene, Washington.

Trigonal, inequilateral, with narrow umbones and moderately inturned beaks; beaks near the anterior one-third; posterior dorsal margin sloping obliquely downward, joining ventral margin in a broad curve; ligament and escutcheon not evident on type material; sculpture of about 37 ribs (range 35-40), ribs on posterior slope weak, remainder low, rounded, with narrow interspaces; hinge of right valve not seen; of left valve with one weak posterior lateral tooth, a weak posterior cardinal (2b), a stronger anterior cardinal (2a), and a slender anterior lateral; interior of shell not exposed.

Dimensions.—Holotype, height, 23 mm., length, 23.5, convexity (one valve), 8; paratype, height, 21 mm., length, 22, convexity (one valve), 7. Average dimensions of 60 specimens: height, 24.3 mm., length, 24.5. Largest specimen: height, 42 mm., length, 42, convexity (one valve), 13.

Repositories.—Holotype, Stanford Univ. Paleo. Type Coll., No. 8302, paratype, No. 8303. Other paratypes, Univ. Calif. Mus. Paleo., No. 32913, from U.C. loc. 9011 (4 specimens); paratypes to be deposited in California Acad. Sci., U.S. National Museum, Paleontological Research Institution, and British Museum (Nat. Hist.).

Type locality.—Stanford Univ. loc. NP-235, Chehalis and Summit Sts., Aberdeen, Washington, collected by Harold Hannibal, 1912 (16 specimens). Montesano formation, upper Miocene-lower Pliocene.

Other localities.—Stanford Univ. locs. NP-221, between Satsop and Elma; NP-220, Sylvia Creek, near head; NP-236, sec. 33, T. 18 N., R. 9 W.; NP-237, 3 mi. above mouth of Wishkah River; NP-240, 3/4 mi. E. of mouth of Wishkah River; NP-244, W. fork Wishkah River 15 mi. N. of Aberdeen; Univ. California loc. 9011, Wishkah River; all in Grays Harbor Co., Washington, Montesano formation.

Matrix.—All specimens were in a gray, hard, poorly sorted, calcite-cemented sandstone.

Remarks.—This is one of the smaller species of *Clinocardium.* It has been confused by authors with *C. coosense,* from which it differs by its fewer ribs and greater obliquity. It resembles *C. blandum* of the Recent fauna but has a thicker, heavier shell.

Species of **Clinocardium**

In order to show better the relationships of the above-named new species of *Clinocardium* to others of the genus, comparisons are made in the form of a key, with footnote references and notes on available illustrations and range. Two west American forms are not included in the key—a. *Cardium decoratum* Grewingk[10] for which type material is unavailable and no subsequent records have been published (records under this name from Puget Sound are of *C. comoxense* Dall, a form now considered inseparable from *C. ciliatum*) ; and b. *Cardium* (*Cerastoderma*) *ciliatum brooksi* MacNeil[11], homonym of *Cardium* (*Papyridea*) *brooksi* Clark, 1932, which is a *Fulvia.* Also not included in the key are the following species from northern Japan and Kamchatka:

braunsi (Tokunaga), 1906. Pleistocene, Japan and Sakhalin I.
bülowi (Rolle), 1896. Recent. Japan.
fastosum (Yokoyama), 1927. Pliocene, Japan.
iwasiroense (Nomura), 1935. Miocene, Japan.
pseudofastosum (Nomura), 1937. Pliocene, Japan.
rhomboideum (Khomenko), 1934. L. Miocene, Sakhalin I. (*fide* Slodkewich, 1938)
shinjiense (Yokoyama), 1923. Miocene, Japan.
shiobarense (Yokoyama), 1926. Miocene, Japan.

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[10] Grewingk, C., 1850. Verh. Russisch-Kaiserlichen Mineral. Gesell. St. Petersburg, Jahr. 1848-9, p. 347, pl. 4, figs. 3 a-g. Aleutian Islands, "Jungste Tertiärzeit" [?Pleistocene].

[11] MacNeil, F. S., 1943. Jour. Paleont., vol. 17, p. 91, pl. 15, fig. 14. Pleistocene, near Nome, Alaska. Not a variant of *C. ciliatum* but probably a local form of *C. californiense,* which Dall, followed by MacNeil, confused with *C. ciliatum.*

KEY TO THE SPECIES OF *CLINOCARDIUM* OF WESTERN NORTH AMERICA

1. Ribs of posterior area crowded and crumpled into an irregular channel .... *californiense*[12]
Ribs of posterior area not forming an irregular channel 2

2. Ribs of anterior slope more widely spaced than on remainder of shell, triangular in cross section 3
Ribs of anterior slope not more widely spaced, rounded to rectangular in cross section 4

3. Length of shell greater than height .... *ciliatum*[13]
(Including *C. comoxense*)[14]
Length of shell less than height .... *yakatagense*[15]

4. Shell markedly inequilateral, oblique 5
Shell subequilateral, not oblique 8

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[12] *Cardium californiense* Deshayes, 1839. Rev. Zool. Soc. Cuvierienne, vol. 2, p. 360; vol. 4, 1841, pl. 47. "Mers de Californie" [actually Kamtschatka]. Range: Neogene to Recent, Kamchatka; Recent, northern Japan to Alaskan Peninsula. Well figured by Grant and Gale, San Diego Soc. Nat. Hist., Mem., vol. 1, pl. 19, fig. 16 (not fig. 13, which is of C. *fucanum*), 1931.

[13] *Cardium ciliatum* Fabricius, 1780. "Fauna Grönlandiae", p. 410. Greenland. Range: Pleistocene of British Columbia and eastern Canada to Recent, Bering Sea, Arctic Ocean, and North Atlantic. Well figured by Grant and Gale, *op. cit.*, pl. 19, fig. 11.

[14] *Cardium californiense comoxense* Dall, 1900. Wagner Free Inst. Sci., Trans., vol. 3, pt. 5, p. 1093. Pleistocene, Vancouver I., British Columbia. Figured by Grant and Gale, *op. cit.*, pl. 19, fig.12, as *C. decoratum*. Holotype now figured for the first time, Pl. 1, figs. 5, 7, 8. Not a variant of *C. californiense* but of *C. ciliatum*; probably not distinguishable, according to statistical measurements summarized in an unpublished doctoral thesis (Frances Wagner, "Paleontology and Stratigraphy of the Marine Pleistocene Deposits of Southwestern British Columbia", Stanford University, 1954).

[15] *Cardium (Cerastoderma) yakatagensis* Clark, 1932. Geol. Soc. Amer., Bull., vol. 43, p. 813, pl. 18, fig. 8. Yakataga formation, southern Alaska, "upper Oligocene" (probably Pliocene, judging by preservation of periostracum).

5. Usually large, ribs fewer than 35, noded 6
Size small to medium, ribs more than 35, not noded 7

6. Ribs 34 in number .... *nuttalli*[16]
("*C. corbis* Martyn" auctt.)
Ribs 28 .... *meekianum*[17]

7. Ribs about 37 in number; height of shell equal to length .... *hannibali*
Ribs about 44; length of shell greater than height .... *pristinum*

8. Ribs 45 or more in number; height of shell not the same as length 9
Ribs fewer than 45, usually about 40; height and length equal . . 10

9. Ribs about 45; height of shell greater than length .... *coosense*[18]
Ribs more than 45; height of shell less than length .... *fucanum*[19]

10. Maximum size of adult shells about 37 mm. ...... *praeblandum*
Maximum size of adult shells about 25 mm. .... *blandum*[20]

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[16] *Cardium nuttallii* Conrad, 1837. Acad. Nat. Sci. Philadelphia, Jour., vol. 7, p. 229, pl. 17, fig. 3. Near Columbia River, Oregon. Range: Upper Miocene to Recent, California west and north to Kamchatka. Well figured, Grant and Gale, *op. cit.*, pl. 19, fig. 17.

[17] *Cardium meekianum* Gabb, 1866. Paleont. California, vol. 2, p. 27, pl. 7, fig. 46. Pliocene, Humboldt Co., Calif. Range: Upper Pliocene, California, Oregon, Washington, Kamchatka; Plio-Pleistocene, Alaska. Hinge figured, Schenck and Keen, "California Fossils for the Field Geologist," pl. 6, figs. 1-2, 1940.

[18] *Cardium (Cerastoderma) coosense* Dall, 1909. U. S. Geol. Survey, Prof. Paper 59, p. 118, pl. 13, figs. 3-4. Pliocene, Coos Bay, Oregon. Holotype refigured, Weaver, Univ. Washington Publ. Geol., vol. 5, pl. 36, fig. 12, (1942) 1943.

[19] *Cardium fucanum* Dall, 1907. Nautilus, vol. 20, p. 112. Puget Sound, Washington. Range: Pleistocene, S. California; Recent, Sitka, Alaska to Monterey, California. Holotype figured, Schenck and Keen, Mém. Soc. de Biogéographie, 7, pl. 2, figs. 21-24, 1940; Schenck, Jour. Paleont., vol. 19, pl. 67, figs. 22-25, 1945.

[20] *Cardium blandum* Gould, 1850. Boston Soc. Nat. Hist., Proc., vol. 3, p. 276. Puget Sound, Washington. Range: Pleistocene, southern California; Recent, Puget Sound area. Holotype figured, Schenck and Keen, 1940, *op. cit.*, pl. 2, figs. 17-20; Schenck, *op. cit.*, pl. 67, figs. 18-21.

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PLATE

Plate 1 (29)

EXPLANATION OF PLATE 1 (29)

Figure Page

1, 6. **Clinocardium praeblandum** Keen, n. sp. 15

1. Paratype, left valve, Univ. Calif., No. 14835, ×1.
6. Holotype, right valve, U.C. No. 14836, ×1.
Upper Miocene, Briones formation, Contra Costa Co., Calif.

2-4. **Granocardium (Ethmocardium) pomeyroli** Keen, n. sp. 8

2. Paratype, right valve, Stanford Univ. Paleo. Type Coll. No. 8289; latex cast, ×1. 3. Paratype, left valve, S.U. No. 8288, latex cast, ×1. 4. Holotype, internal mold. S.U. No. 8287, ×1. Upper Cretaceous, Moméa area, New Caledonia.

5, 7, 8. **Clinocardium comoxense** Dall, 1900 19

U. S. Nat. Mus., No. 427772; photograph courtesy of Dr. H. A. Rehder. ×1. Pleistocene, Vancouver I.

9, 15. **Clinocardium pristinum** Keen, n. sp. 16

9. Paratype, right valve, U.C., No. 14837, ×1. 15. Holotype, left valve, U.C., No. 14838, ×1. Upper Miocene, Neroly formation, Contra Costa Co., Calif.

10, 13. **Nemocardium (Arctopratulum) ezoense** Takeda, 1953 12

10. Refigured paratype (Takeda, 1953, pl. 11, fig. 1). 13. Refigured holotype (*ibid.*, pl. 9, fig. 4) ×1, photographs courtesy H. Takeda. Oligocene, Hokkaido I., Japan.

11. **Nemocardium (Nemocardium) semiasperum** (Deshayes), 1858 9

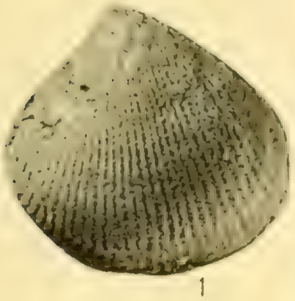
Reproduction of original figure (Anim. s. Vert. Bassin Paris, vol. 1, pl. 55, fig. 1 [part]), for comparison with fig. 12.

12, 14, 17. **Nemocardium (Arctopratulum) griphus** Keen, n.sp. 12

12. Paratype, right valve, S.U., No. 8296, ×1. 14. Holotype, S.U., No. 8295, ×1. 17. Detail of sculpture of holotype, ×3. Middle Miocene, Astoria formation, Wash.

16. **Clinocardium hannibali** Keen, n.sp 18

Holotype, S.U., No. 8302, ×1. Mio-Pliocene, Montesano formation, Wash.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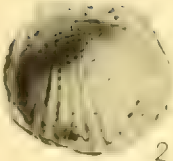
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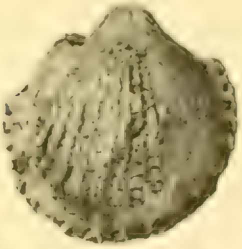
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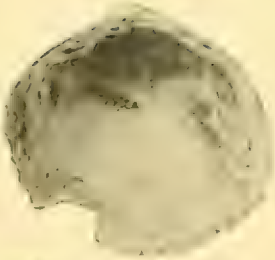
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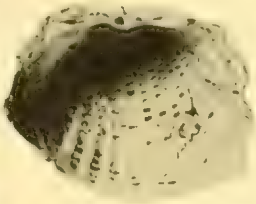
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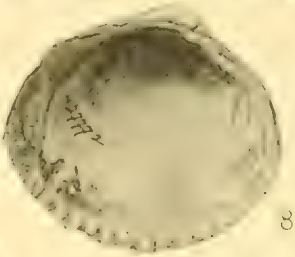
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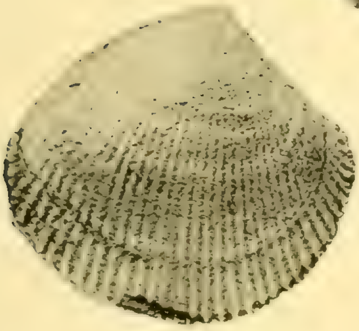
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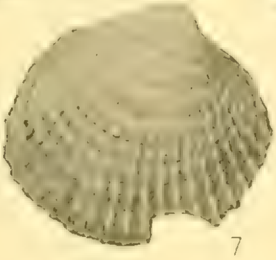
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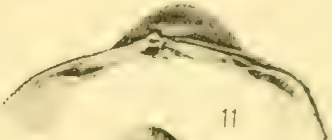
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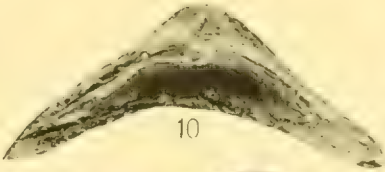
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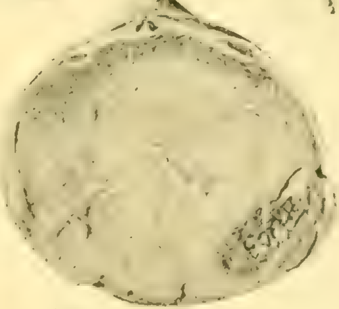
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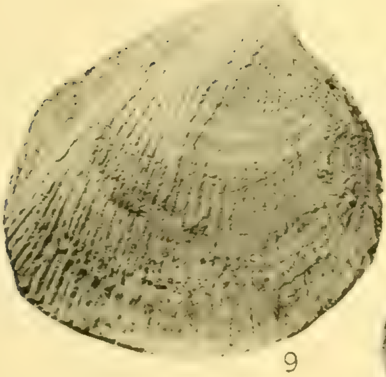
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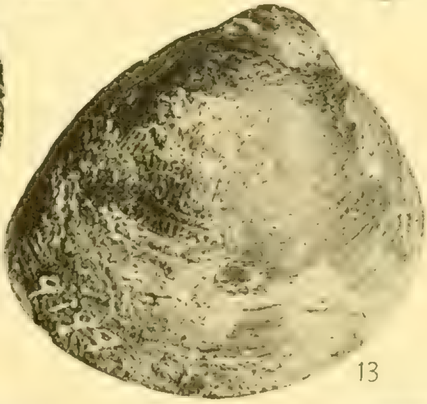
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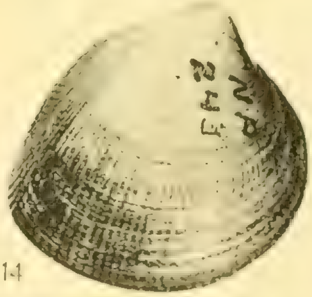
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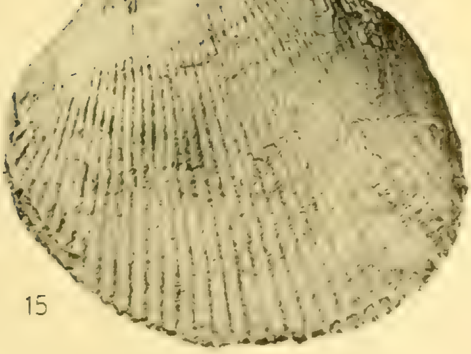
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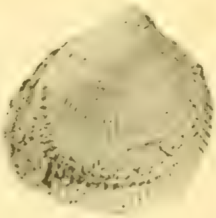
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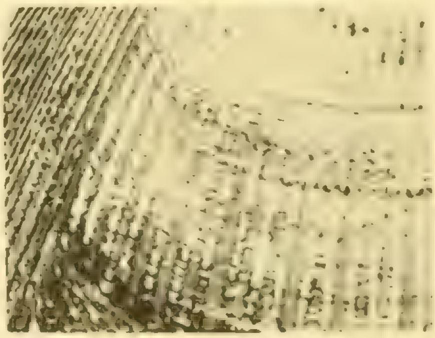
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No. 154

UPPER DEVONIAN OSTRACODA FROM THE CERRO GORDO FORMATION OF IOWA

By

Lee B. Gibson
Creole Petroleum Corporation, Maracaibo, Venezuela

April 14, 1955

Paleontological Research Institution
Ithaca, New York, U.S.A.

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UPPER DEVONIAN OSTRACODA FROM THE CERRO GORDO FORMATION OF IOWA[1]

LEE B. GIBSON

Creole Petroleum Corporation, Maracaibo, Venezuela

ABSTRACT

Twenty-four species belonging to fourteen different genera are described from the Cerro Gordo formation of Iowa. Twenty-three species and two genera (*Bekena* and *Morrisites*) are described as new. The genus *Plagionephrodes* is reported for the first time from the Devonian.

INTRODUCTION

Few papers devoted to Upper Devonian Ostracoda of North America have appeared in the literature. Papers mentioning single species have been published by Kindle (1919) and Burgess (1931). With the exception of Branson's (1944) inclusion of a single plate of figures taken from an unpublished thesis (Becker, 1940) and a short article by Cooper (1942) mentioning the available ostracode fauna of the Cerro Gordo formation, Upper Devonian Ostracoda remain a neglected field of study.

The Cerro Gordo formation as exposed in the collected area consists of a yellow, fairly calcareous clay with occasional discontinuous bands of shaly limestone. The basal portion of the formation contains many iron-stained nodules and rests disconformably upon the uniform calcareous gray shale of the Independence formation. The greater portion of the exposure consists of the *Spirifer* zone of Fenton (1924) which contains an abundant macrofauna of brachiopods, gasteropods, and bryozoans of the Cordilleran type. Along with the Ostracoda occur the foraminiferal species *Endothyra gallowayi* Thomas (1931) [*Nanicella gallowayi* Henbest (1951)] and the trochiliscid species of Peck (1934).

It is significant that the ostracode fauna from the Cerro Gordo bears a Mississippian rather than a Devonian aspect. The absence of the forms which usually dominate the Middle Devonian is striking, *i.e.*, *Ulrichia*, *Bollia*, *Octonaria*, and *Ponderodictya*. Four genera present in the Cerro Gordo are also reported from the Middle Devonian with several species of *Bairdia.* Although Bairdias have been reported from earlier beds, those of the Cerro Gordo are more Carboniferous-like in form. The Cerro Gordo fauna also contains several Beecherellas and many *Plagionephrodes. Plagionephrodes* has previously been reported from the Mississippian only.

---

[1] Based on a thesis presented to the graduate board of Washington University, St. Louis, Missouri, in partial fulfillment of the degree of Master of Arts.

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The author thanks Dr. W. H. Shideler for making available the described material from the collections of Miami University, Oxford, Ohio. Thanks are also extended to Dr. J. Wolford of Miami University, who collected the samples during 1939 at Rockford, Iowa, and who made available to the author his field notes, thereby facilitating a subsequent trip to the area by the author. The writer wishes to express his gratitude and thanks to Mrs. Betty Kellett Nadeau for her guidance in this work and to Mr. Robert Morris for his many helpful suggestions.

LOCALITY

All of the Ostracoda described in this paper were taken from the upper 20 feet (*Spirifer* zone) of the Cerro Gordo formation at a clay pit operated by the Rockford Brick and Tile Company of Rockford, Iowa.

ILLUSTRATIONS

All illustrations are photographs of types which have been treated with ammonium chloride following the simple method outlined by Teichert (1948).

SYSTEMATIC DESCRIPTIONS

Family **APARCHITIDAE** Ulrich and Bassler, 1923

Genus **MACRONOTELLA** Ulrich, 1894

Macronotella Ulrich, 1894, Geol. Minnesota, vol. 3, pt. 2, p. 684, figs. 30-34.

Type species.—Macronotella scofieldi Ulrich by original designation. Black River limestone (Ordovician), Cannon Falls, Minnesota.

Range.—Middle Ordovician to Upper Devonian.

Macronotella punctulifera Gibson, n.sp. Pl. 2, fig. 5

Description.—Carapace subcircular in outline; both valves equal (apparent overlap in figure due to a shearing of the valves); carapace with a definite "anterior swing"; anterior margin more broadly curved than posterior; margins meet cardinal angles shallowly; surface coarsely reticulate in an irregular pattern; unornamented centrodorsal spot present on both valves; hingement of the left valve unknown; hingement of the right valve consists of a sharp ridge extending the entire length of the hinge line; anteriorly this ridge develops a triangular toothlike elevation and posteriorly a keel-like elevation which extends slightly below the cardinal angle.

Dimensions.—Holotype: whole carapace, length, 0.87 mm.; height, 0.57 mm.; width, 0.30 mm.

Repository.—Holotype: United States National Museum, No. 123108.

Remarks.—*Macronotella punctulifera* differs from the type species in having a shorter hingeline, in being more circular in outline, and in the anterior and posterior margins being more smoothly continuous with the dorsal margin. *M. elongata* Kay (1940, pl. 30, fig. 12) differs from the new species in having a more acuminate postventral margin. *M. punctulifera* resembles species of *Schmidtella* Ulrich in general outline but lacks the ventral overlap of that genus. The new species also resembles *Bertillonella subcircularis* Stewart and Hendrix (1945, pl. 11, fig. 1) in general outline but lacks the concentric surface ornamentation. *M. punctulifera* is rare in the Cerro Gordo formation.

Family **YOUNGIELLIDAE** Kellett, 1933

Genus **YOUNGIELLA** Jones and Kirkby, 1895

Youngia Jones and Kirkby, 1886, Geol. Assoc. London, Proc., vol. 9, p. 515.

Youngiella Jones and Kirkby, 1895, Ann. Mag. Nat. Hist., ser. 6, vol. 16, p. 455, pl. 21, figs. 5a, d.

Type species.—*Youngia rectidorsalis* Jones and Kirkby (1886) by original designation. Carboniferous of England.

Range.—Upper Devonian to Middle Permian.

Youngiella ? sp. Pl. 1, fig. 12

Description.—Carapace elongate and subrectangular in outline;

dorsal margin straight and parallel to the ventral margin; anterior and posterior margins broadly rounded; greatest length measured at midheight; surface of carapace smooth.

Dimensions.—Hypotype: whole carapace, length, 0.60 mm.; height, 0.30 mm.; width, 0.15 mm.

Repository.—Hypotype: United States National Museum, No. 123132.

Remarks.—Due to poor preservation and the few specimens found, more specific typing was not possible, and the specimens are questionably referred to the genus *Youngiella.*

Superfamily **BEYRICHIACEA** Ulrich and Bassler, 1923

Family **KLOEDENELLIDAE** Ulrich and Bassler, 1923

Genus **JONESINA** Ulrich and Bassler, 1908

Beyrichia fastigata Jones and Kirkby, 1865, Geol. Soc. Glasgow, Tr., 2, p. 219.

Jonesina Ulrich and Bassler, 1908, U. S. Nat. Mus., Proc., vol. 35, p. 324.

Jonesina Coryell and Booth, 1933, Amer. Midl. Nat., vol. 15, No. 3, p. 272, figs. 11-12.

Jonesina Cooper, 1941, Illinois State Geol. Surv. Rept., Inves., No. 77, p. 55, pl. 11, figs. 6-7, 15-16, 36-39.

Type species.—*Beyrichia fastigata* Jones and Kirkby (1865) by subsequent designation. Carboniferous of England.

Range.—Upper Devonian to Middle Permian.

Jonesina biloba Gibson, n.sp. Pl. 1, figs. 4a-c

Description.—Carapace small and subelliptical in outline; hingeline straight and interrupted anteriorly by a small steplike process; ventral margin broadly convex and inclined; anterior margin broadly rounded and higher than the posterior. The free margin is raised around the entire outline except along the dorsal margin. A prominent sulcus opens onto the dorsal margin at midlength. Two nodes are developed immediately below the hingeline and on either side of the median sulcus. An irregular swelling is located in the ventral half of each valve and extends from below the anterior cardinal angle to just below the posterior node. Greatest height and thickness in the anterior quarter; surface of the valves appear minutely reticulate; valves equal; hingement unknown.

Dimensions.—Holotype: whole carapace, length, 0.51 mm.; height, 0.30 mm.; width, 0.21 mm.

Repository.—Holotype: United States National Museum, No. 123098.

Remarks.—*Jonesina biloba* differs from the type species in being more elliptical in outline and possessing the steplike termination of the hingeline at the anterior cardinal angle. The new species appears to be more lobated than *J. grahamensis* Coryell and Booth (1933, pl. 272, fig 6). The Pennsylvanian forms described by Cooper (1941) are more elliptical in dorsal outline and lack the discontinuity of the dorsal margin. This species is rare in the Cerro Gordo formation.

Jonesina ? sp. Pl. 1, fig. 6

Description.—Carapace subrectangular in outline; hingeline straight and paralleling the ventral margin; posterior and anterior margins broadly rounded; two prominent sulci are present, one approximately at midlength, and one in the anterior third of the carapace; both sulci deepen toward and open onto the dorsal margin. The areas immediately surrounding the sulci are conspicuously inflated, the posterior swelling being more pronounced than the anterior. Greatest height measured along the ventral and dorsal margins; greatest length between maximum convexities of the anterior and posterior margins; greatest thickness in the posterior third; shell wall thin; surface of carapace minutely and irregularly punctate.

Dimensions.—Hypotype: Single valve (damaged), length, 0.75 mm.; height, 0.57 mm.; width, 0.21 mm.

Repository.—Hypotype: United States National Museum, No. 123099.

Remarks.—By nature of the condition of the single specimen found, more specific typing was not possible. The presence of the sulci and the nodularlike swellings along the dorsal margin of the species seems to indicate an affinity with *Jonesina.*

Family **KIRKBYIDAE** Ulrich and Bassler, 1923

Genus **KIRKBYELLA** Coryell and Booth, 1933

Kirkbyella Coryell and Booth, 1933, Amer. Midl. Nat., vol. 15, No. 3, p. 262, pl. 3, fig. 7.

Kirkbyella Coryell and Cuskley, 1934, Amer. Mus. Nov., No. 748, p. 2, figs. 1, 2.

Kirkbyella Coryell and Malkin, 1936, Amer. Mus. Nov., No. 891, p. 2, fig. 13.

Kirkbyella Stewart and Hendrix, 1945, Jour. Paleont., vol. 19, No. 2, p. 90, pl. 10, figs. 12-14.

Type species.—Kirkbyella typa Coryell and Booth by original designation. Wayland shale (Pennsylvanian), Graham, Texas.

Range.—Lower Devonian to Upper Pennsylvanian.

Kirkbyella devonica Gibson, n.sp. Pl. 1, fig. 15

Description.—Carapace long and subtriangular in outline; hingeline straight and paralleling the ventral margin; anterior and posterior margins broadly rounded, the anterior meeting the dorsal margin more abruptly than the posterior; free margins elevated along the anterior, ventral, and posterior margins. A prominent sulcus is located just posterior to midlength. A conspicuous longitudinal ridge begins gradually just below the midheight immediately anterior to midlength and extends posteriorly, becoming confluent with the posterior margin. Surface of the valve coarsely reticulate in an irregular pattern.

Dimensions.—Holotype: right valve, length, 0.75 mm.; height, 0.39 mm.; width, 0.15 mm.

Repository.—Holotype: right valve, United States National Museum, No. 123104. Paratype: left valve, United States National Museum, No. 123105.

Remarks.—Kirkbyella devonica differs from the type species in being more rectangular, in not possessing a sinuate dorsal margin, and in having a less abrupt termination posteriorly of the longitudinal ridge. Known Hamilton *Kirkbyella* differ from *K. devonica* in possessing abrupt spinelike terminations of the longitudinal ridge. This species is uncommon in the Cerro Gordo formation.

Genus **AMPHISSITES** Girty, 1910

Amphissites carmani ? Stewart and Hendrix Pl. 1, figs. 10a-b

Amphissites carmani Stewart and Hendrix, 1945, Jour. Paleont., vol. 19, No. 2, p. 106, pl. 1, figs. 10a-b.

Description.—Carapace subrectangular in outline; dorsal margin slightly concave; ventral margin broadly rounded; anterior and posterior margins obtusely rounded. A small ridge or flange parallels the ventral margin and extends along the anterior and posterior margins to the cardinal angles; an elongate node is located centrodorsally in each valve; two prominent vertical ridges which extend to the dorsal margin are present in the anterior and posterior portions of each valve. Greatest length measured in the dorsal half; greatest height in anterior half. Surface of the carapace is strongly reticulate. Hingement of the left valve consists of a groove into which fits the ridge of the right valve; a slight flangelike projection is present at each cardinal angle.

Dimensions.—Hypotype: left valve, length, 0.87 mm.; height, 0.45 mm.; width, 0.12 mm.

Repository.—Hypotype: left valve, United States National Museum, No. 123083. Hypotype: right valve, United States National Museum, No. 123082.

Remarks.—The specimen figured by Stewart and Hendrix (1945) shows a marginal ridge slightly in from the edge. The specimens figured in this paper do not show this as they are younger molts. More mature forms, however, do show a submarginal flange but were not figured as they have been badly distorted due to crushing. This species is common in the Cerro Gordo formation.

Genus **ROUNDYELLA** Bradfield, 1935

Roundyella Bradfield, 1935, Bull. Amer. Paleont., vol. 22, No. 73, p. 66.

Sansabella ? curiosa Stewart and Hendrix, 1945, Jour. Paleont., vol. 19, No. 2, p. 101, pl. 11, figs. 9-10.

Roundyella Cooper, 1946, Illinois State Geol. Surv., Bull. 70, pp. 108-109, pl. 17, figs. 29-36.

Type species.—Roundyella simplicissimus Bradfield (1935) by original designation. Stanton formation, Nebraska.

Range.—Middle Devonian to Upper Permian.

Roundyella fimbriamarginata Gibson, n.sp. Pl. 2, fig. 2

Description.—Carapace subelliptical in outline, small; dorsal margin straight; ventral margin straight and slightly inclined to the dorsum; anterior and posterior margins broadly rounded; greatest height in anterior quarter; greatest thickness along the ventral quarter. A short submarginal ridge extends along the free margins to the cardinal angles. Valves equal except along the center where the left slightly overlaps the right. Surface of the carapace finely reticulate. Hingement of the left valve consists of a sharp ridge extending the entire length of the dorsal margin, terminated at each cardinal angle by small depressions. Hingement of the right valve unknown.

Dimensions.—Holotype: whole carapace, length, 0.63 mm.; height, 0.36 mm.; width, 0.27 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123131. Paratype: left valve, United States National Museum, No. 123130.

Remarks.—The distinguishing features of *Roundyella fimbriamarginata* are the slight inclination of the ventral margin toward the dorsum and the submarginal ridge. These features serve to differentiate this species from previously described forms of *Roundyella.* This species is rare at Rockford, Iowa.

Family **AECHMINIDAE** Swartz, 1936

Genus **AECHMINELLA** Harlton, 1933

Aechminella Harlton, 1933, Jour. Paleont., vol. 7, No. 1, p. 20, pl. 6, figs. 9a-b, pl. 7, figs. 1a-b.

Type species.—*Aechminella trispinosa* Harlton (1933) by original designation. Johns Valley shale (Pennsylvanian), southern Oklahoma.

Range.—Upper Devonian to Lower Pennsylvanian.

Aechminella fimbriata Gibson, n.sp. Pl. 1, fig. 2

Description.—Carapace subquadrate in outline; hingeline long and straight and terminated with obtuse cardinal angles; ventral margin broadly rounded and smoothly continuous with the anterior and posterior margins; anterior margin more broadly rounded than the posterior; a thin marginal flange projects ventrolaterally along the entire ventral margin and vanishes dorsally along the anterior and posterior margins. Three large spines are present along the dorsal margin of the valve: a larger spine is located centrally along the hingeline and curves posteriorly, a smaller seems to be developed from the anterior basal portion of the median spine, and posteriorly a short spine is developed just beneath the cardinal angle. Greatest thickness and greatest height just anterior to midlength; surface of the valve finely reticulate. Hingement of the right valve consists of a thin groove surmounted on a narrow ridge which extends the entire length of the dorsal margin; at the cardinal angles two tear-shaped sockets are developed, the anterior being the larger. Hingement of the left valve unknown.

Dimensions.—Holotype: right valve, length, 0.51 mm.; height, 0.33 mm.; width, 0.12 mm.

Repository.—Holotype: right valve, United States National Museum, No. 123083.

Remarks.—*Aechminella fimbriata* differs from previously described *Aechminella* in having a weaker development of the spines and in possessing a ridge which extends along the ventral margin. The species is rare at Rockford, Iowa.

Family **ACRONOTELLIDAE** Swartz, 1936

Genus **MONOCERATINA** Roth, 1928

Monoceratina Roth, 1928, Jour. Paleont., vol. 2, No. 1, pp. 16-19, fig. 1.

Monoceratina Warthin, 1934, Contrib. Mus. Paleont., Univ. Michigan, vol. IV, No. 12, p. 207, pl. I, fig. 1.

Type species.—*Monoceratina ventrale* Roth (1928) by original designation. Wapanucka limestone (Pennsylvanian), Pontotoc County, Oklahoma.

Range.—Middle Devonian to Recent.

Monoceratina ? levinsoni Gibson, n.sp. Pl. 2, figs. 9a-c

Description.—Carapace small and semicircular in outline; hingeline straight, making over two-thirds of the carapace length; ventral margin broadly convex and inclined to the dorsum; anterior margin more broadly rounded and higher than the posterior; greatest height at midlength; greatest thickness produced by the spine located centroventrally. A prominent spine is developed at midlength along the ventral margin and projects posterolaterally. The post-cardinal angle is extended in a vertical spinelike projection slightly above the dorsal margin. Minute papillae are arranged concentrically along the anterior and posterior margins. Surface of the carapace smooth and broadly convex; hingement unknown.

Dimensions.—Holotype: complete carapace, length, 0.78 mm.; height, 0.51 mm.; width, 0.39 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123106.

Remarks.—*Monoceratina levinsoni* differs from the type species in being more circular in outline and in possessing a postcardinal spine as well as anterior and posterior marginal papillae. It differs from previously described forms in being relatively higher and posteriorly less truncate. There have been no similar forms described from the Devonian or Lower Mississippian of North America. This species is rare in the Cerro Gordo formation.

This species is named in honor of Dr. Stuart A. Levinson of the Humble Oil Company.

Superfamily **CYPRACEA** Ulrich and Bassler, 1923

Family **BAIRDIIDAE** Sars, 1887

Genus **BAIRDIA** McCoy, 1844

Bairdia McCoy, 1844, Synoptic Characters of Carboniferous Fossils of Ireland, p. 164, pl. 23, fig. 6.

Bairdia Kellett, 1934, Jour. Paleont., vol. 8, No. 2, pp. 120-138, pls. 14-18.

Bairdia Morey, 1935, Jour. Paleont., vol. 9, No. 4, pp. 322-324, pl. 28, figs. 12, 17, 20, 22.

Bairdia Sylvester-Bradley, 1950, Ann. Mag. Nat. Hist., ser. 12, vol. III, pp. 751-756.

Type species.—*Bairdia curta* McCoy (1844) by original designation. Mountain limestone, Mississippian, Ireland.

Range.—Middle Silurian to Recent.

Bairdia hypsoconcha Gibson, n.sp. Pl. 1, fig. 16

Description.—Carapace stubby and subrhomboidal in outline; dorsal margin conspicuously convex; anterodorsal margin extends in a nearly straight line to a blunt beak located at midheight; postdorsal margin extends in a broad arch to the sharp posterior beak at midheight; hingeline straight and slightly inclined posteriorly; ventral margin weakly convex, somewhat flattened at midlength where a liplike extension of the left valve overlaps the right; greatest height and thickness at midlength. The overlap of the left valve is conspicuous along the hingeline and the postdorsal margin, becoming less pronounced along the anterodorsal margin.

Dimensions.—Holotype: complete carapace, length, 0.96 mm.; height, 0.57 mm.; width, 0.45 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123085.

Remarks.—Bairdia hypsoconcha—No species of *Bairdia* described from the Olentangy shale by Stewart and Hendrix (1945) or from the basal Mississippian by Morey (1935) were found similar to the new species. It is more closely related to the Permian species *B. garrisonensis* Upson (1935). However, *B. hypsoconcha* has a greater overlap along the postdorsal margin, a slightly longer hingeline, and a sharper anterior beak. There is also a superficial resemblance to *B. beedei* Ulrich and Bassler (1906) but differs from it in being more stubby, in not possessing so great an overlap along the dorsal margin, and in having a shorter hingeline. This species occurs rarely.

Bairdia notoconstricta Gibson, n.sp. Pl. 1, figs. 17a-b

Description.—Carapace large and subdeltoid in outline. Hingeline straight and slightly inclined posteriorly; anterodorsal margin extends briefly in a straight line to the smooth, blunt beak at midheight; posterodorsal margin steeply inclined and shallowly concave to the sharp posterior beak located below midheight; ventral margin broadly convex, produced at the lower limit of the anterior margin into an abrupt greater convexity. Periphery of the left and right valves nearly equal along the anterior and posterior margins. A conspicuous shallow constriction of the valves appears at midlength immediately anterior to the area of greater thickness. Greatest height in the anterior third; greatest thickness in the posterior third.

Dimensions.—Holotype: complete carapace, length, 1.17 mm.; height, 0.66 mm.; width, 0.45 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123087.

Remarks.—Bairdia notoconstricta—There are no *Bairdia* previously described from the Devonian or the Mississippian which are similar to *B. notoconstricta*. The middorsal constriction of the valves and the abrupt convexity of the anterior margin appears singularly significant. The anterior ventral extension of the margin recalls a similar structure in the genus *Bairdites* and also, but in a more faint expression, in the genus *Silinites*. This is a common species in the Cerro Gordo formation.

Bairdia subtilla Gibson, n.sp. Pl. 1, figs. 14a-b

Description.—Carapace elongate and subrhomboidal in outline; dorsal margin broadly arched with the hingeline slightly inclined posteriorly; anterodorsal margin weakly convex to a well-rounded anterior beak located at midheight; posterodorsal margin extends in a straight line to the sharp posterior beak just below midheight; ventral margin broadly arched and shallowly inclined to meet the posterior beak; greatest height in the anterior third; greatest thickness at midlength; inner marginal areas clear along the anterior, ventral, and posterior margins.

Dimensions.—Holotype: left valve, length, 1.05 mm.; height, 0.54 mm.; width, 0.12 mm.; Paratype: right valve, length, 0.96 mm.; height, 0.51 mm.; width, 0.09 mm.

Repository.—Holotype: left valve, United States National Museum, No. 123089. Paratype: right valve, United States National Museum, No. 123090.

Remarks.—*Bairdia subtilla* differs from *B. subparallella* Morey (1935) in being more elongate and in possessing a shorter hingeline. The new species bears a close relationship to *B. subtilla* Cooper (1941, pl. 2, figs. 5-6). This species occurs rarely in the Cerro Gordo formation.

Bairdia extenda Gibson, n.sp. Pl. 1, fig. 18

Description.—Carapace obtusely trapezoidal in outline; dorsal margin faintly convex and not inclined; anterodorsal margin faintly convex and shallowly inclined to the anterior margin which it meets sharply at midheight; postdorsal margin straight and steeply inclined to the sharp posterior beak located in the ventral quarter; ventral margin sinuate with a pronounced convexity at midlength; anterior margin broadly convex to midheight (this area is damaged in the figured specimen); overlap slight, being more pronounced along the hingeline, and to a lesser degree along the dorsal margin; greatest height measured from the anterior cardinal angle; greatest thickness midlength; dorsal outline elliptical.

Dimensions.—Holotype: complete carapace, length, 1.41 mm.; height, 0.60 mm.; width, 0.51 mm.

Repository.—Holotype: complete specimen, United States National Museum, No. 123084.

Remarks.—Bairdia extenda most closely resembles *B. glennesis* Kellett (1935) from which it differs in having a shorter hingeline, in being relatively less elongate, and in having a sharper posterior beak. The two species are similar in general outline, and it is probable that they are of common lineage. A single complete carapace from the Cerro Gordo formation.

Bairdia rockfordensis Gibson, n.sp. Pl. 1, fig. 8

Description.—Carapace subreniform in outline, high, and relatively thick. Dorsal margin strongly arched; anterodorsal margin broadly convex and continuing into the anterior margin broadly; posterodorsal margin straight and steeply inclined, meeting the posterior beak well below midheight; ventral margin concave midlength; anterior margin broadly rounded (slightly damaged in the figured specimen); greatest height and thickness midlength. The left valve overlaps the right weakly along the entire outline except at the anterior and posterior beaks where the valves appear equal; a prominent liplike extension of the left overlaps the right along the ventral concavity.

Dimensions.—Holotype: complete carapace, length, 1.32 mm.; height, 0.75 mm.; width, 0.48 mm.

Repository.—Holotype: complete carapace United States National Museum, No. 123088.

Remarks—There are no previously described Devonian species which are similar to *B. rockfordensis,* as also there have been no similar Mississippian forms described. A somewhat close resemblance to the new species is found in *Bythocypris bosquetiana* Brady, a Recent form, figured by Sars (1928, p. 64, pl. 29). *B. rockfordensis* is rare in the Cerro Gordo formation.

Bairdia lancelata Gibson, n.sp. Pl. 1, fig. 11

Description.—Carapace elongate, subelliptical; hingeline straight and of moderate length; anterodorsal margin long and almost straight, becoming rounded at midheight; posterodorsal margin straight and broadly angular; ventral margin almost straight (specimen illustrated slightly damaged posteriorly); greatest height and thickness in midquarter; dorsal outline of carapace smoothly elliptical; overlap slight but greatest along the hingeline and dorsal slopes; liplike extension of the left valve overlaps the right along the ventral margin at midlength.

Dimensions.—Holotype: whole carapace, length, 1.47 mm.; height, 0.54 mm.; width, 0.45 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123086.

Remarks.—*Bairdia lancelata* bears no resemblance to any previously described forms from the Devonian or Mississippian. In general the species is somewhat similar to *Bairdia trojana* Wilson (1933), but the new species is posteriorly less acuminate and anteriorly more narrowly elliptical. This new species is rare in the Cerro Gordo formation.

Genus **BEKENA** Gibson, n.gen.

Type species.—Here designated *Bekena diaphrovalvis* Gibson, n.sp. Cerro Gordo formation (Upper Devonian), Rockford, Iowa.

Diagnosis.—The genus *Bekena* is here established to include those bairdiocyprid and bythocyprid-like forms having distinctly flattened and depressed areas bordering the anterior and posterior margins.

Description.—Carapace subtriangular to subreniform in outline; dorsal margin strongly arched with the anterior and posterior slopes being nearly equal in length and in angle; ventral margin almost straight to convex; anterior margin broadly rounded with the posterior margin more sharply arched; greatest height at midlength or slightly in front; left valve larger and overlaps the right strongly along the dorsal margin; overlap extends from the upper quarter of the anterior margin to well below midheight along the posterior border; a liplike extension of the left valve over the right may be weakly or strongly developed along the ventral margin about midlength; right valves moderately to strongly compressed in areas bordering the anterior and posterior margins; surface of carapace smooth.

Bairdiocypris moravica Kegel (1927) resembles closely the new species *Bekena diaphrovalvis* in possessing the anterior and posterior marginal depressions of the right valve and in general outline of the carapace. More pronounced overfolding of the dorsal margin of the later form serves to distinguish them. Both species are placed in *Bekena* as neither form resembles *Bairdiocypris gerolsteinensis* Kegel (1927), the type species of *Bairdiocypris.* The species lacks the marginal depressions of the right valve. Such a feature is uncommon in the family Bairdiidae. *Bairdia pecki* Morey (1935), though lacking a pronounced overfolding of the dorsal margin, is also placed in *Bekena* as it possesses the anterior and posterior marginal depressions of the right valve as found in *B. diaphrovalvis.*

Range.—Upper Devonian to Lower Mississippian.

This genus is named in honor of Mrs. Betty Kellett Nadeau.

Bekena diaphrovalvis Gibson, n.sp. Pl. 1, figs. 9a-d

Description.—Carapace large, subreniform in outline; dorsal margin strongly convex; ventral margin evenly and broadly convex; anterior margin more broadly rounded and higher than the posterior; greatest height slightly in front of midlength; greatest thickness slightly posterior of midlength; dorsal margin strongly overfolded in a continuous line extending from below midheight posteriorly to near midheight along the anterior margin; right valve smaller and subrectangular in outline; hingeline straight and occupying nearly the middle third of the valve; ventral margin concave immediately anterior of midlength; anterior margin broadly rounded and depressed immediately bordering the free edge; posterior margin depressed and narrowly rounded, postcardinal area angular; carapace smooth, thick and broadly convex except for the flattened areas along the anterior and posterior margins; hingement of the left valve unknown; right valve bears a sharp ridge extending the entire length of the hingeline; ridge also bears a shallow and narrow groove extending along its entire length.

Dimensions.—Holotype: complete carapace, length, 1.59 mm.; height, 0.96 mm.; width, 0.63 mm. Paratype: left valve, length, 1.50 mm.; height, 0.90 mm.; width, 0.45 mm. Paratype: right valve, length, 1.50 mm.; height, 0.74 mm.; width, 0.24 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123093. Paratype: left valve, United States National Museum, No. 123094. Paratype: right valve, United States National Museum, No. 123092.

Remarks.—Bekena diaphrovalvis has been placed in the Bairdiidae because of the wide valve overlap, the general outline of the carapace, and the hingement. In North America it can be compared only with *Bairdia pecki* Morey (1935) which has a similar anterior and posterior marginal structure but lacks the strong overfolding of the dorsal margin and the subtriangular outline of the new species. This species is common in the Cerro Gordo formation.

Bekena ? sp. Pl. 1, fig. 13

Description.—Carapace large and subelliptical in outline; dorsal margin strongly convex; ventral margin nearly straight; anterior and posterior margins broadly rounded; greatest height and thickness midlength; surface of the right valve narrowly impressed along the anterior and posterior margins; overlap more pronounced along the straight hingeline and less evident along the postdorsal margin; surface of carapace smooth.

Dimensions.—Hypotype: damaged whole carapace, length, 1.32 mm.; height, 0.81 mm.; width, 0.63 mm.

Repository.—Hypotype: United States National Museum, No. 123095.

Remarks.—Only one damaged specimen was recovered from the Cerro Gordo formation. Therefore, the author has not attempted specific typing of the form. The specimen is probably closely allied to the new genus *Bekena* by virtue of the marginal depressions of the smaller right valve.

Family **BEECHERELLIDAE** Ulrich, 1891

Genus **BEECHERELLA** Ulrich, 1891

Beecherella Ulrich, 1891, Amer. Geol., vol. 8, p. 198; Miller, 1892, North Amer. Geol. Paleont., Appendix 1, p. 705; Ulrich, 1894, Geol. Minnesota, vol. 3, pt. 2, p. 691; Ulrich and Bassler, 1923, Maryland Geol. Surv., Silurian, p. 318, text fig. 24.

Bairdia lenticulata (?) Stewart, 1945, Jour. Paleont., vol. 19, No. 2, p. 110, pl. 12, fig. 11.

Type species—Beecherella carinata Ulrich by original designation. Helderbergian (New Scotland), Lower Devonian, Albany County, New York.

Range.—Lower to Upper Devonian.

Beecherella trapezoides Gibson, n.sp. Pl. 1, figs. 5a-b

Description.—Carapace trapezoidal in outline; dorsal margin straight and makes two-thirds of the carapace length; ventral margin shallowly convex; anterior and posterior cardinal areas obtuse; posterior and anterior extremities terminated by blunt points below midheight; greatest height immediately anterior of midlength; greatest thickness at midlength; dorsal overlap continuous until terminated at the anterior and posterior beaks; ventral overlap conspicuous at midlength where a liplike extension of the left valve overlaps the right; cross section subtriangular with convex sides.

Dimensions.—Holotype: complete carapace, length, 0.84 mm.; height, 0.33 mm.; width, 0.30 mm.

Repository.—Holotype: United States National Museum, No. 123091.

Remarks.—The author has placed the new species *Beecherella trapezoides* in the Beecherellidae because of the anterior and posterior terminations of the carapace into spinelike extensions of the valves and because of the triangular cross section. The species is closely allied to *Bairdia lenticulata* Stewart and Hendrix (1945) in general outline (orientation the opposite of that given here). This species is fairly common at Rockford, Iowa.

Genus **MORRISITES** Gibson, n.gen.

Type species.—Morrisites gibbosus Gibson, n.sp., here designated. Cerro Gordo formation (Upper Devonian), Rockford, Iowa.

Description.—Carapace small with a straight hingeline and trapezoidal outline; ventral margin broadly convex or possibly straight; anterior and posterior terminations of the carapace pointed; posterior third of carapace inflated; anterior third flattened and compressed into a keel-shaped structure. Overlap probably left over right; surface of carapace smooth.

This genus is named in honor of Robert W. Morris of the American-Arabian Oil Company.

Morrisites gibbosus Gibson, n.sp. Pl. 1, figs. 7a-b

Description.—Carapace small and trapezoidal in outline; hingeline straight and more than three-quarters the carapace length; ventral margin broadly convex, with a deep posterior swing; anterior and posterior margins meet the hingeline dorsally at well rounded obtuse angles and ventrally meet the ventral margin below midheight in sharp points; greatest height and greatest thickness just posterior to midlength; dorsal outline of carapace tear-shaped; hingement unknown.

Dimensions.—Holotype: complete carapace, length, 0.84 mm.; height, 0.33 mm.; width, 0.36 mm.

Repository.—Holotype: United States National Museum, No. 123107.

Remarks.—*Morrisites gibbosus*—The single specimen recovered from the Cerro Gordo formation, though intact, has been somewhat distorted by what appears to be a secondary growth of calcite along the valve contacts; the thinner anterior portion of the valves has a slightly twisted aspect. The new species is tentatively placed in the Beecherellidae on the basis of the probable overlap and the general outline of the carapace. There have been no forms described from the geologic formations of North America to which the new species may be compared.

Superfamily **CYTHERACEA** Ulrich and Bassler, 1925

Family **ROPOLONELLIDAE** Coryell and Malkin, 1936

Genus **EUGLYPHELLA** Warthin, 1934

Strepula Jones, 1890 (part), Geol. Soc. London Quart. Jour., vol. 46, pl. 11, pl. 2, fig. 4.

Euglyphella Warthin, 1934, Mus. Pal. Univ. Michigan, Contr. 4, No. 12, p. 220.

Type species.—Strepula sigmoidalis Jones (1890) by subsequent designation. Devonian of England.

Range.—Middle to Upper Devonian.

Euglyphella subquadrata Gibson, n.sp. Pl. 2, figs. 8a-b

Description.—Carapace subrectangular in outline; dorsal margin long and straight; ventral margin inclined dorsally and slightly concave at midlength; anterior margin broadly rounded; posterior margin more sharply rounded and not so high as the anterior; greatest height in anterior quarter; greatest thickness midlength; free margins and dorsum of carapace raised; each valve ornamented with high carinae, the larger forming an almost complete circle which becomes flattened anteriorly and which surrounds another smaller coil following the configuration of the larger; both sets of ridges seem to blend into a common area just anterior to and below the postcardinal angle near the ventral margin; the larger left valve overlaps the right along all margins; hingement of the left valve consists of a groove extending the entire length of the dorsal margin, with an elliptical ridgelike tooth at the anterocardinal angle and a small socket beneath the posterocardinal angle; hingement of the right valve consists of a sharp ridge extending along the dorsal margin; anteriorly an elliptical socket develops at the cardinal angle and posteriorly an elongate but small tooth is formed.

Dimensions.—Holotype: left valve, length, 0.81 mm.; height, 0.45 mm.; width, 0.18 mm. Paratype: complete carapace, length, 0.87 mm.; height, 0.48 mm.; width, 0.30 mm.

Repository.—Holotype: left valve, United States National Museum, No. 123096. Paratype: complete carapace, United States National Museum, No. 123097.

Remarks.—Euglyphella subquadrata differs from the type species in that the posterior margin is more bluntly rounded and interrupted at the ventral margin by an obtuse angle. Another difference lies in the displacement of the carinae. In the type species, the dorsal limb of the main carinae nearly fuses with the dorsal margin slightly behind the anterior cardinal angle. In *E. subquadrata* the carinae are well within the limits of the valve outline and closed postventrally. The new species differs from previously described forms in being less sharply triangular in outline and possessing a closed arrangement of the carinae. This species is common at Rockford, Iowa.

Family **THLIPSURIDAE** Ulrich, 1894

Genus **PLAGIONEPHRODES** Morey, 1935

Plagionephrodes Morey, 1935, Jour. Paleont., vol. 9, No. 4, pp. 318-319, pl. 28, figs. 23, 16.

Plagionephrodes Becker, 1940, in Branson, Geology of Missouri, Univ. Missouri Studies, vol. 19, p. 149, pl. 24, figs. 36-40.

Type species.—Plagionephrodes uninodosus Morey by original designation. Basal Mississippian sandstone, Williamsburg, Missouri.

Description.—The close relationship which *Plagionephrodes* bears to *Ropolonellus* Van Pelt and *Euglyphella* Warthin has been recognized by Morey (1935, p. 318). There is also a similarity between the new species *Plagionephrodes allotriovalvis* and species of the genus *Quasillites* Coryell and Malkin (1936) figured in this report. Similarity lies in general outline, hingement, and surface reticulations; this relationship is more evident in the younger molts. The number of individuals of *Plagionephrodes* was large in the Cerro Gordo fauna, the amount being well over a hundred. The new species *Plagionephrodes bicostalis* and *Plagionephrodes werneri* seem closely allied to the species figured by Becker (1940) from the Snyder Creek formation of Missouri.

Plagionephrodes bicostalis Gibson, n.sp. Pl. 2, figs. 1a-c

Description.—The valves vary in general outline, the left is subtriangular and the right is nearly oval; carapace subtriangular in outline; dorsal margin weakly convex; ventral margin convex and inclined dorsally; anterior margin broadly rounded and raised in both valves to flangelike structures which originate at midheight and extend to the anterior cardinal angles; posterior margin short and obtusely rounded; greatest height in the anterior quarter; greatest thickness midlength. Two prominent ridges are present on each valve originating immediately below the hingeline and extending to the ventral quarter. In both valves the shorter posterior ridge has an extremely abrupt dorsal termination. On the left valve a prominent toothlike spine is located along and slightly in from the edge of the postventral margin; another short, posteriorly directed spine is located at the dorsal margin. Both the right and left valves bear a short spine located along the ventral third of the posterior margin near the edge. Surfaces of both valves between flanges and ridges smooth. Hingeline impressed with the left overlapping the right along the entire dorsal margin and less extensively along the anterior ventral and posterior margins. Articulation of the left valve consists of a groove extending the entire length of the dorsal margin; anteriorly this groove became obscured by an overfolding of the anterodorsal margin; posteriorly the groove is extended into a broad depression at the posterocardinal angle. Hingement of the right valve consists of a ridge extending along the dorsal margin and which is terminated anteriorly by a cleft and posteriorly by a broad swelling at the cardinal angle.

Dimensions.—Holotype: complete specimen, length, 0.87 mm.; height, 0.54 mm.; width, 0.36 mm. Paratype: left valve, length, 0.93 mm.; height, 0.57 mm.; width, 0.24 mm. Paratype: right valve, length, 0.84 mm.; height, 0.39 mm.; width, 0.18 mm.

Repository.—Holotype: complete specimen, United States National Museum, No. 123109. Paratype: left valve, United States National Museum, No. 123111. Paratype: right valve, United States National Museum, No. 123110.

Remarks.—The presence of the two prominent ridges on the right and left valves, and the broad toothlike spine along the postventral margin of the left valve serves to distinguish *Plagionephrodes bicostalis* from the type species and from other species of *Plagionephrodes* in the Cerro Gordo fauna. It differs from the type species *P. uninodosus* Morey in being more triangular in outline, and although the positions of the ridges are approximately equivalent in both species, they are better developed in *P. bicostalis*. The species is rare at Rockford, Iowa.

Plagionephrodes allotriovalvis Gibson, n.sp. Pl. 2, figs. 3a-e

Description.—Valves differ in outline and in ornamentation; the left is obesely triangular and smooth while the right is nearly oval and bears fine surface reticulation; carapace subrhomboidal in outline; dorsal margin weakly convex; ventral margin concave at midlength and shallowly inclined to the dorsum; anterior margin broadly rounded, becoming flattened at midheight by a flange which extends to the anterior cardinal angle in the left valve and to slightly above the midheight in the right valve; posterior margin more narrowly rounded. In both the right and left valves two pairs of posteriorly directed spines are developed in the posterior quarter; one pair is situated just above midheight, and the other is located just below midheight along the posterior margin slightly in from the edge. At the posterior cardinal angle of the left valve a small spine is developed. The female carapace is smaller, stubby, and triangular in outline. Hingement of the left valve consists of a dorsal marginal groove. The groove opens beneath the anterior cardinal angle into the interior of the valve, and posteriorly widens into a cleftlike depression at the level of the postcardinal spine. The hingement of the right valve is comprised of a dorsal marginal ridge which expands anteriorly into a keel-like structure. This keel-like structure is prolonged ventrally to a point immediately below the cardinal angle. Posteriorly the dorsal ridge is terminated by a toothlike elevation just below the cardinal angle.

Dimensions.—Holotype: complete carapace, length, 0.90 mm.; height, 0.54 mm.; width, 0.30 mm. Paratype: left valve, length, 0.90 mm.; height, 0.57 mm.; width, 0.18 mm. Paratype: right valve, length, 0.78 mm.; height, 0.42 mm.; width, 0.12 mm. Paratype: left valve, female, length, 0.72 mm.; height, 0.48 mm.; width, 0.15 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123101. Paratype: left valve, United States National Museum, No. 123102. Paratype: right valve, United States National Museum, No. 123103. Paratype: left valve, female, United States National Museum, No. 123100.

Remarks.—The new species *Plagionephrodes allotriovalvis* is differentiated from *P. bicostalis* by the absence of the two prominent vertical ridges and the broad toothlike spine along the ventral margin of the left valve. It closely resembles *Senescella longaeva* Stewart and Hendrix (1945). *Senescella* may be a synonym of *Plagionephrodes* as both forms are similar in outline and in the positions occupied by the spines. It is interesting to note that the new species is similar in hingement, surface reticulation, and in general outline of both right and left valves to species of the genus *Quasillites*. This species is abundant in the Cerro Gordo formation.

Plagionephrodes shideleri Gibson, n.sp. Pl. 2, figs. 4a-d

Description.—Carapace subrhomboidal in outline; individual valves differ in shape, the left is subrhomboidal and the right oval; dorsal margin weakly convex; ventral margin convex and inclined to the dorsum; anterior margin broadly rounded. In the left valve, the margin develops a flange at midheight which extends to the cardinal angle; the same flange in the right valve begins at midheight and ends abruptly in the dorsal quarter. Posterior margin narrowly rounded, meeting the dorsal margin obtusely. Greatest height in anterior quarter; greatest thickness midlength. Both the right and left valves possess spines in the posterior quarter just below the dorsal margin and along the ventral quarter of the posterior margin slightly in from one edge. A broad toothlike spine is located along the postventral margin of the left valve with a small posteriorly directed spine at the postcardinal angle. The left valve has a weak ridge in the anterior quarter. The surface of the right valve is deeply impressed at the anterior quarter. Surface of carapace smooth between flanges and ridges. Hingement of the left valve consists of a groove extending along the dorsal margin. This groove becomes obscured anteriorly by an overfolding of the dorsal margin; it ends beneath the posterior cardinal angle in a semicircular depression. Hingement of the right valve consists of a ridge extending the entire length of the dorsal margin. This ridge becomes exaggerated into broadened hemicircular cusps at the anterior and posterior cardinal angles.

Dimensions.—Holotype: complete carapace, length, 0.93 mm.; height, 0.51 mm.; width, 0.33 mm. Paratype: left valve, length, 0.84 mm.; height, 0.54 mm.; width, 0.18 mm. Paratype: right valve, length, 0.75 mm.; height, 0.36 mm.; width, 0.18 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123112. Paratype: left valve, United States National Museum, No. 123113. Paratype: right valve, United States National Museum, No. 123114.

Remarks.—*Plagionephrodes shideleri* is similar to *P. bicostalis* in outline, hingement, in possessing a broad toothlike spine along the postventral margin of the left valve and in the number and positions of the spines developed around the posterior margin. It differs from *P. bicostalis* by lacking the posterior ridge of the left valve and possessing but a faint expression of the anterior ridge of the same valve. This species is common in the Cerro Gordo formation.

This species is named in honor of Dr. W. H. Shideler, formerly of Miami University, Oxford, Ohio.

Plagionephrodes werneri Gibson, n.sp. Pl. 2, figs. 6a-d

Description.—Valves differ radically in outline and in size, the left is large and wedge-shaped, the right is small and oval; carapace subtriangular in outline; dorsal margin nearly straight; ventral margin weakly convex at midlength and inclined to the dorsum; anterior margin broadly rounded and high; posterior margin brief and weakly arched. The anterior margin possesses a thick flange which originates at midheight and extends to the anterocardinal angle. The flange of the right valve begins at midheight and extends dorsally to the upper third of the valve. A short spine is developed dorsally just below the hingeline in the posterior third of both the right and left valves. This spine may be present as a short barlike process in the left valve. A second small and posteriorly directed spine occurs along the posteroventral margin of both valves. Surface of the right valve minutely and irregularly punctate, surface of the left smooth.

Dimensions.—Holotype: complete carapace, length, 0.87 mm.; height, 0.51 mm.; width, 0.33 mm. Paratype: left valve, length, 0.90 mm.; height, 0.51 mm.; width, 0.18 mm. Paratype: right valve, length, 0.84 mm.; height, 0.42 mm.; width, 0.15 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123115. Paratype: left valve, United States

National Museum, No. 123116. Paratype: right valve, United States National Museum, No. 123117.

Remarks.—The new species *Plagionephrodes werneri* differs from the species of this genus with which it occurs in being more triangular in outline. It differs also from *P. bicostalis* and *P. shideleri* in the lack of a postmarginal spine of the left valve and in the hingement. There is, however, a similarity in the hingement of *P. werneri* and *P. allotriovalvis*. Both species possess shelflike teeth or flanges as components of the right hinge at both the anterior and posterior cardinal angles. In general outline, *P. werneri* also bears a somewhat close resemblance to *Ropolonellus dubius* Stewart and Hendrix (1945). This species is abundant in the Cerro Gordo formation.

The species is named in honor of Dr. Courtney Werner of Washington University, St. Louis, Missouri.

Famly **QUASILLITIDAE** Coryell and Malkin, 1936

Genus **QUASILLITES** Coryell and Malkin, 1936

Quasillites Coryell and Malkin, 1936, Amer. Mus. Nov., No. 891, pp. 17-19, figs. 36, 38.

Quasillites Swartz and Oriel, 1948, Pennsylvania State Coll., Min. Exp. Sta., Tech. Pap., 142, pp. 55-56, pl. 79, figs. 18-21, pl. 80, figs. 1-18.

Type species.—*Quasillites obliquus* Coryell and Malkin by original designation. Widder beds (Hamilton), Ontario, Canada.

Range.—Middle to Upper Devonian.

Quasillites beachi Gibson, n.sp. Pl. 2, figs. 7a-m

Description.—Valves differ in outline, the left is larger and more triangular, and the right is smaller with an oval outline and arched dorsal margin; carapace subrectangular in outline; dorsal margin straight; ventral margin straight and inclined to the dorsum; anterior margin higher and more broadly rounded than the posterior; greatest height in the anterior quarter; greatest thickness midlength; surface of the carapace beset with small reticulations partially and crudely arranged in a vertical series; a less ornamented and somewhat depressed spot is present centrodorsally on each valve. The male carapace is more elongate and possesses a longer ventral margin which nearly parallels the dorsum. Dorsally both male and female are elliptical in outline and bear at the posterior cardinal angle a liplike extension of the left valve overlapping the right. The left hinge component includes an impressed ridge extending the length of the dorsal margin. At the cardinal angles this ridge ends at an elliptical socket anteriorly and posteriorly at a smaller socket. Hinge of the right valve consists of a fairly sharp ridge along the dorsal margin which also bears a groove along its entire length. Beneath both the anterior and posterior cardinal angles short elliptical flanges are developed. Left overlaps the right along all margins; overlap most conspicuous along the anterior and posterior margins.

Dimensions.—Holotype: complete carapace, female, length, 0.75 mm.; height, 0.48 mm.; width, 0.33 mm. Paratype: left valve, female, length, 0.78 mm.; height, 0.51 mm.; width, 0.24 mm. Paratype: right valve, female, length, 0.75 mm.; height, 0.45 mm.; width, 0.18 mm. Paratype: complete carapace, male, length, 0.81 mm.; height, 0.39 mm.; width, 0.38 mm. Paratype: left valve, male, length, 0.78 mm.; height, 0.45 mm.; width, 0.21 mm. Paratype: right valve, male, length, 0.72 mm.; height, 0.39 mm.; width, 0.15 mm.

Repository.—All types are in the United States National Museum. Holotype: complete carapace, female, No. 123118. Paratype: left valve, female, No. 123119. Paratype: right valve, female, No. 123123. Paratype: complete carapace, male, No. 123120. Paratype: left valve, male, No. 123121. Paratype: right valve, male, No. 123122.

Remarks.—The author knows of no previously described forms from the Devonian or Mississippian which resemble the new species *Q. beachi.* Though the species lacks the ventral spine along the postventral margin described in other species of *Quasillites* and has surface reticulations instead of ridges, it agrees with the generic description in general outline, hingement, and in the difference between the outlines of the individual valves according to Swartz and Oriel (1948, p. 555). This species is abundant in the Cerro Gordo formation.

This species is named in honor of Paul R. Beach of Houston, Texas.

Quasillites hackberryensis Gibson, n.sp. Pl. 1, figs. 1a-d

Description.—Valves differ in outline, the left is triangular and the right is oval with a strongly convex dorsum; carapace subtriangular in outline; dorsal margin of carapace weakly convex; ventral margin convex and inclined to the dorsum; anterior margin more rounded and higher than the posterior; greatest height in the anterior quarter; greatest thickness midlength; surface ornamented with fine ridges and grooves mostly vertically arranged; these ridges radiate from a less ornamented centrodorsal spot and become vertically arranged toward the lateral extremities of the carapace. Hinge elements as in the new species *Q. beachi* previously described.

Dimensions.—Holotype: complete carapace, length, 0.72 mm.; height, 0.48 mm.; width, 0.39 mm. Paratype: left valve, length, 0.72 mm.; height, 0.48 mm.; width, 0.24 mm. Paratype: right valve, length, 0.66 mm.; height, 0.36 mm.; width, 0.18 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123127. Paratype: left valve, United States National Museum, No. 123128. Paratype: right valve, United States National Museum, No. 123129.

Remarks.—The new species *Q. hackberryensis* possesses the more typical ornamentation of the Quasillitidae but also lacks the postventral spine of the type species. It differs from previously described forms in lacking this spine. In general, the surface ornamentation found on the new species is much finer than that found on forms described from Lower Devonian sections. This species is abundant.

Quasillites ellipticus Gibson, n.sp. Pl. 1, figs. 3a-d

Description.—Carapace long, ovoid in outline; dorsal margin broadly convex; ventral margin weakly rounded; anterior margin more arcuate than the posterior; greatest height and thickness midlength; right valve somewhat more flattened along the dorsal margin than the left and smaller; surface ornamented with concentric fingerprintlike ridges; a small less ornamented spot is located centrodorsally. Hinge of the left valve consists of a depressed ridge extending the entire length of the dorsal margin. At the cardinal angles elliptical clefts are developed. The right hinge component includes a narrow ridge extending along the dorsal margin, superimposed upon which is a shallow groove; at each cardinal angle there is an elliptical tooth, the anterior being larger than the posterior.

Dimensions.—Holotype: complete carapace, length, 0.75 mm.; height, 0.45 mm.; width, 0.39 mm. Paratype: left valve, length, 0.78 mm.; height, 0.48 mm.; width, 0.24 mm. Paratype: right valve, length, 0.75 mm.; height, 0.42 mm.; width, 0.12 mm.

Repository.—Holotype: complete carapace, United States National Museum, No. 123124. Paratype: left valve, United States National Museum, No. 123126. Paratype: right valve, United States National Museum, No. 123125.

Remarks.—As with the other species of the genus *Quasillites* described in this paper, the new species *Q. ellipticus* lacks the post-ventral spine of the type species. It differs from the other species here described in the elliptical outline of the carapace. The author agrees with Swartz and Oriel (1948, p. 555) that possible forms with ovate characters referred to as *Spinovina* by Coryell and Malkin (1936) should be included in the *Quasillites*. This species is fairly common in the Cerro Gordo formation, Rockford, Iowa.

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PLATES

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Explanation of Plate 1 (30)

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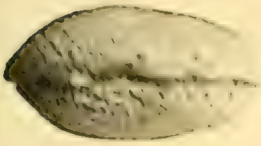
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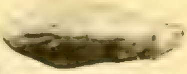
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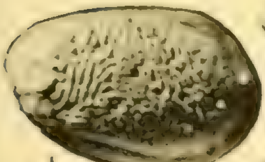
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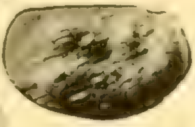
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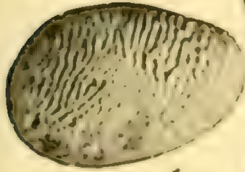
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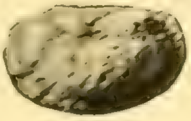
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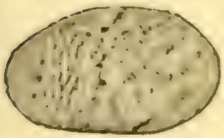
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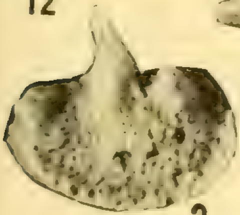
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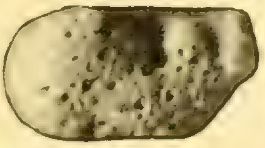
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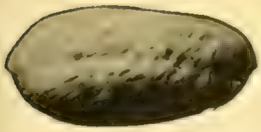
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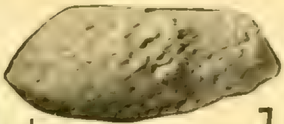
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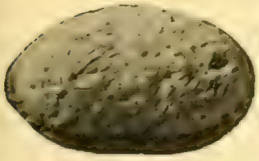
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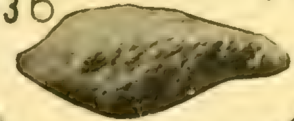
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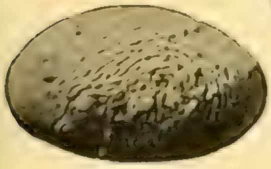
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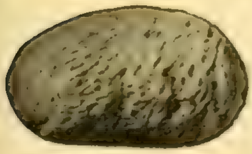
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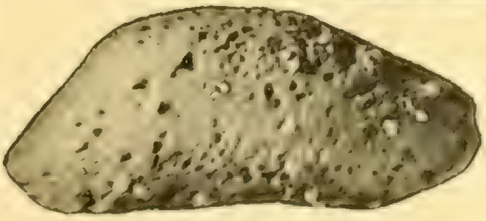
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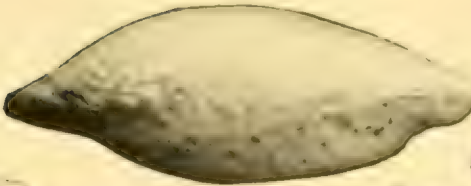
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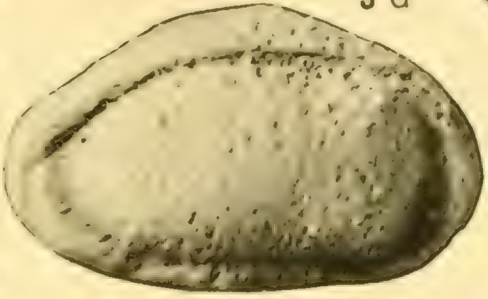
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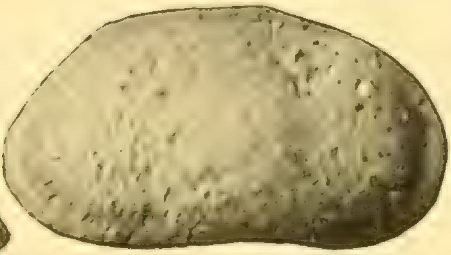
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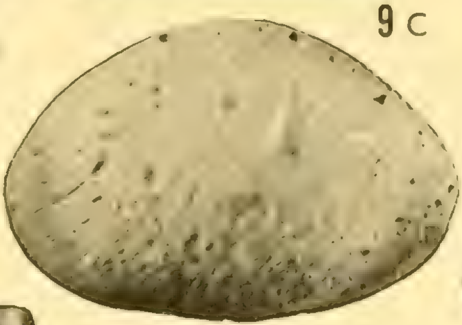
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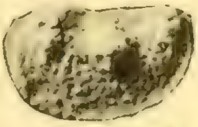
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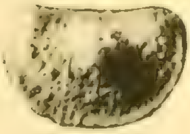
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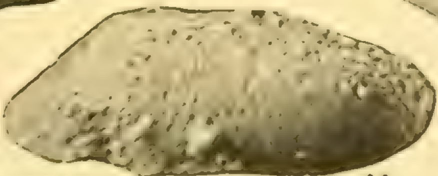
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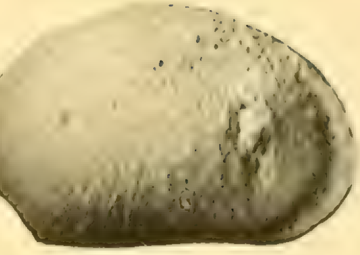
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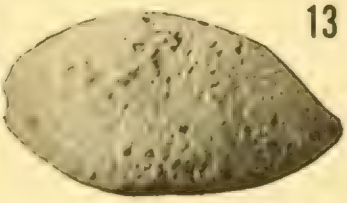
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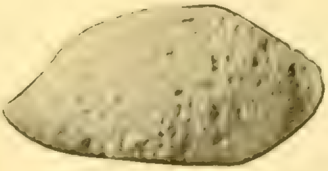
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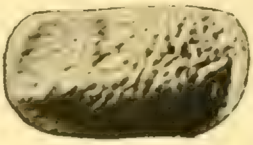
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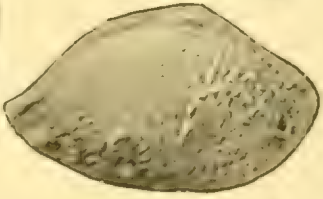
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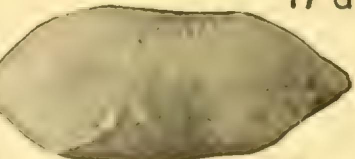
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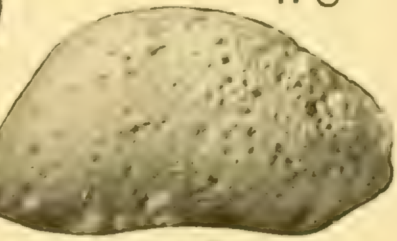
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PLATE 2 (31)

Explanation of Plate 2 (31)

Figure Page

1. **Plagionephrodes bicostalis** Gibson, n.sp. 24
   a. Lateral view of a right valve, × 38, paratype.
   b. Dorsal view of a left valve, × 20, paratype.
   c. Lateral view of a right valve, about × 39, paratype.

2. **Roundyella fimbriamarginata** Gibson, n.sp. 11
   Right lateral view of a whole specimen, holotype, about × 35.

3. **Plagionephrodes allotriovalvis** Gibson, n.sp. 25
   a. Dorsal view of a complete carapace, × 34, holotype.
   b. Lateral view of a left valve, × 33, paratype.
   c. Right lateral view of the holotype, × 34.
   d. Lateral view of a right valve, about × 31, paratype.
   e. Lateral view of a left valve, about × 36, female, paratype.

4. **Plagionephrodes shideleri** Gibson, n.sp. 27
   a-b. Lateral views of left and right valves of paratypes, × 33. c-d. Dorsal and right lateral views of a complete specimen, × 30, holotype.

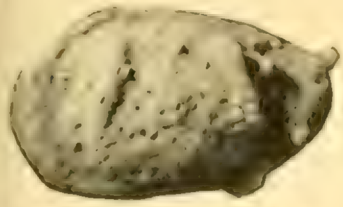
5. **Macronotella punctulifera** Gibson, n.sp. 7
   Right lateral view of a complete carapace, about × 39.

6. **Plagionephrodes werneri** Gibson, n.sp. 28
   a-b. Dorsal and right lateral views of a whole carapace, about × 29, holotype. c-d. Lateral views of a right and left valve, about × 28, paratypes.

7. **Quasillites beachi** Gibson, n.sp. 29
   a-g. Female carapaces. a-b. Dorsal and right lateral views of the holotype, × 33. c. Lateral view of a right valve, × 33, paratype. d-g. Successively younger molts of left valve, paratypes. h-i. Dorsal and right lateral views of a whole male carapace, about × 34, paratype. j. Lateral view of a male right valve, about × 33, paratype. k-m. Successively younger molts of male left valves.

8. **Euglyphella subquadrata** Gibson, n.sp. 23
   a. Lateral view of a left valve, about × 38, holotype.
   b. Right lateral view of a complete carapace (slightly crushed), × 35, paratype.

9. **Monoceratina ? levinsoni** Gibson, n.sp. 13
   a-c. Posterior, right lateral and ventral views of a complete carapace, holotype, × 37.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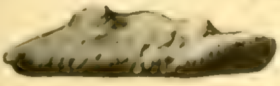
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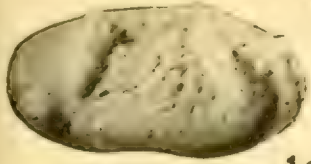
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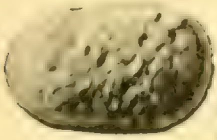
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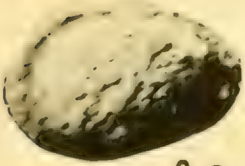
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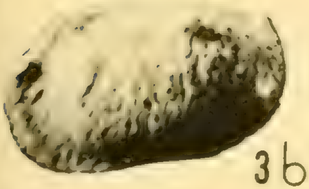
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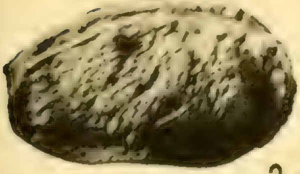
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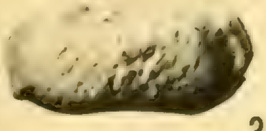
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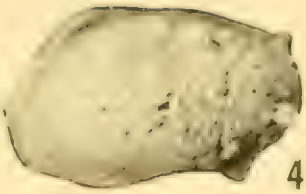
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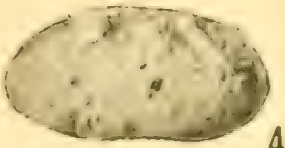
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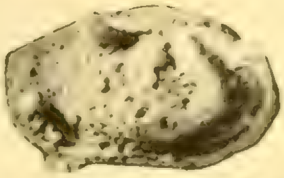
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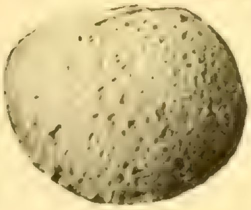
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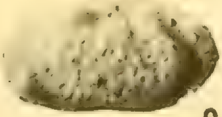
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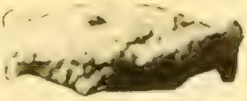
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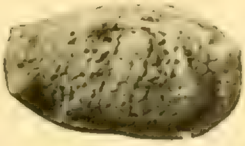
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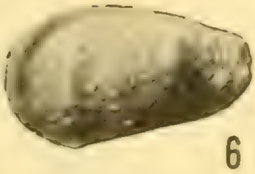
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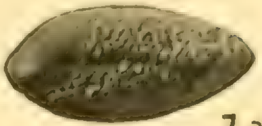
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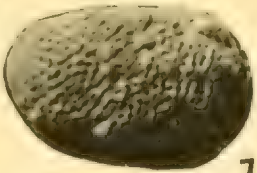
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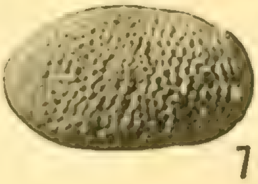
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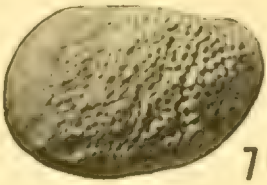
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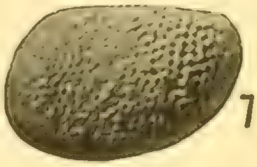
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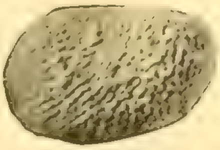
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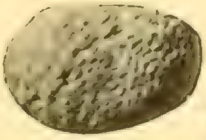
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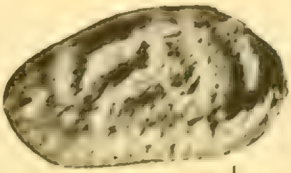
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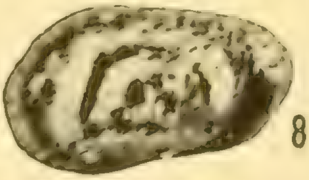
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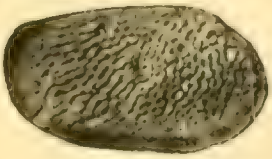
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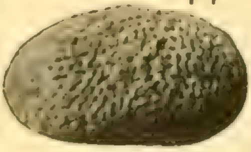
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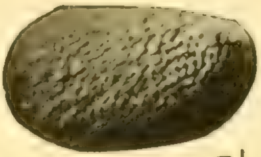
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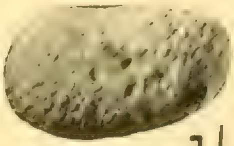
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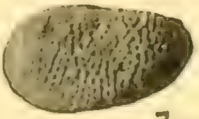
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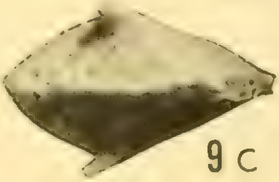
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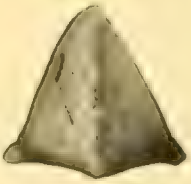
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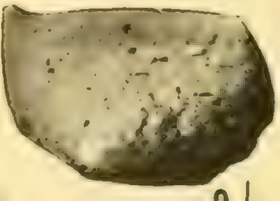
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